BIBLIOGRAPHY ON EXTRACTIVE METALLURGY OF NICKEL AND COBALT, 1900-1928

By CURTIS A. JONES

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Preface

This compilation of literature references, covering the period 1900–1928, inclusive, supplements material published earlier as Information Circular 7805, entitled "Bibliography on Extractive Metallurgy of Nickel and Cobalt, January 1929–July 1955." The first work was issued before the review was completed, to make the modern references immediately available to researchers engaged in intensive work on Cuban laterites under the sponsorship of the General Services Administration of the Federal Government.

While preparing material for this bibliography, the author found a few references that predate 1900, also some that relate to the period January 1929 to July 1955 but were not included in Information Circular 7805. The present circular thus lists several references before 1900 and several after 1928.

Copies of Information Circular 7805 may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 70 cents each.

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BIBLIOGRAPHY ON EXTRACTIVE METALLURGY OF NICKEL AND COBALT, 1900-1928 [1]

BY

CURTIS A. JONES [2]

INTRODUCTION AND SUMMARY

Continuing interest has been shown in developing processes for extracting nickel and cobalt from low-grade domestic deposits of these metals and in improving existing methods. Of special concern is the nickel-recovery installation at Nicaro, Oriente Province, Cuba, operated for the General Services Administration. The Bureau of Mines felt that a bibliography would help familiarize personnel at various Bureau of Mines stations and General Services Administration contractors with extraction methods both in the United States and in foreign countries.

When this task was under way it became apparent that to compile a complete bibliography would require considerable time, so it was decided to limit the first part to the later literature and issue it independently, thus making it available sooner. The present work supplements the first part and extends the coverage to the earliest years of nickel and cobalt metallurgy.

The principal literature indexes consulted were: *Chemical Abstracts*, 1907–34; *British Chemical Abstracts*, 1926–44 (several issues were missing from local files); *Engineering Index*, 1884–1934; *United States Public Documents Catalog*, 1900–1940; and *Metals Review*, 1948–49.

Much of the source material for these references was found in *Chemical Abstracts*. The author gratefully acknowledges this help and wishes also to thank the compilers of *Engineering Index*, *British Chemical Abstracts*, *United States Public Documents Catalog*, and *Metals Review*.

As the indexing arrangement used in the first bibliography has been followed, it is repeated here. Several possible arrangements of references were considered. That chosen as most practicable comprises five main parts: (I) General Metallurgy, (II) Pyrometallurgical, (III) Hydrometallurgical, (IV) Electrometallurgical, and (V) Miscellaneous; each part is subdivided into main headings that are subdivided further. "Nonspecified Ores" includes citations applicable to both oxidized and nonoxidized ores, as well as reports that do not indicate the type of ore treated. Under "Oxidized Ores" will be found not only oxidized ores, but silicate oxide ores and oxides. The subdivision "Nonoxidized Ores" includes all ores not covered by the first two subheadings, such as sulfides and arsenides. A group, including the word "Studies," under parts II, III, and IV lists theoretical discussions on such subjects as thermodynamic equilibria, crystal structure, and electrical passivity in electrowinning a metal. Most of these references include no annotations. Under part V, two primary headings, "Recovery As a Byproduct" and "Recovery From Scrap Sources" seemed necessary to cover some of the material. The primary groupings, "Refining of Metal, Pyrometallurgical," and "Refining of Metal, Electrometallurgical," terminate the bibliography.

[1] Work on manuscript completed February 1958. Titles enclosed in brackets are translations from the language in which the item was published.

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Omitted for the sake of brevity are all references to mining, mineralogy, or geology alone and statements of productions, reserves, etc. Several references have been deleted because their meaning was obscure, because the metallurgical operations were questionable, or because it was believed that their inclusion would add nothing to the cumulative metallurgical knowledge expressed in the other references.

ACKNOWLEDGMENTS

The Bureau of Mines greatly appreciates the interest shown by the General Services Administration in the recovery of critical materials. The cost of preparing this extensive bibliography was partly defrayed by that agency under Contract GS–00–B (D)–1521.

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PART I. GENERAL METALLURGY

GENERAL

NONSPECIFIED ORES

LOCAL METAL ENTERPRISES AND PRODUCING AREAS

1. Angeloti, J. J. Tratamiento quimico-metalurgico de los minerales complejos de cobre, cobalto, niquel, plata y oro, procedentes de los yacimientos de Leon y Asturias. [Chemical-Metallurgical Treatment of Complex Ores of Copper, Cobalt,[1] Nickel, Silver, and Gold from Deposits in Leon and Asturias.] Ing. y Constr., vol. 6, No. 64, April 1928, pp. 182–184; Eng. Index, 1928, p. 1341.

The author describes processes and patented mechanical apparatus for converting ores to sulfates and successive precipitation of desired metals. Extractions were copper 95 percent and nickel and cobalt 85 percent. The metals were refined by electrolysis.

2. Aston, James. Nickel and Cobalt. Min. Ind., vol. 24, 1915, pp. 517–524; Chem. Abs., vol. 11, 1917, p. 136.

Production, imports and exports, and technology are discussed.

3. Bulletin of Imperial Institute. Nickel Industry in Canada. Vol. 15, 1917, pp. 568–575; Chem. Abs., vol. 12, 1918, p. 1630.

Copper may replace considerable Ni in a 3.5-percent Ni steel without producing an inferior article.

4. Canadian Chemical Journal. The Nickel Industry of Canada. Vol. 2, 1918, pp. 40–43; Chem. Abs., vol. 12, 1918, p. 576.

5. Canadian Engineer. Canada's Nickel Industry. Vol. 35, July 12, 1918; Eng. Index, 1918, p. 331.

The Royal Commission reports on Canada's nickel industry.

6. Canadian Mining Journal. The International Nickel Company of Canada, Ltd. Vol. 51, No. 44, Oct. 31, 1930, pp. 1034–1059, 33 figs.; Eng. Index, 1930, p. 1201.

Describes the mines, flotation ore-treatment plants, smelting plant, copper refinery, and sulfuric acid and niter-cake plant of the International Nickel Company of Canada.

7. Carpenter, H. C. H. The Nickel Industry. Nature, vol. 100, 1917, pp. 225–226; Chem. Abs., vol. 12, 1918, p. 349.

Discusses the report of the Royal Ontario Nickel Commission.

8. Cartwright, Cosmo T. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada in 1912. Canadian Dept. of Mines Bull. 256; Chem. Abs., vol. 8, 1914, p. 312.

9. Coleman, A. P. The Nickel Industry; With Special Reference to the Sudbury Region, Ontario. Canadian Dept. Mines Bull. 170, 206 pp.; Chem. Abs., vol. 7, 1913, p. 3294.

Gives description and analyses of all known ore deposits in Ontario; also gives accounts of methods of mining and smelting the ores and of the chief Ni regions of other countries. Appendexes describe patents relating to separating Ni and Cu and refining Ni.

10. Drury, C. W. Cobalt. Min. Ind., vol. 26, 1917, pp. 480–483; Chem. Abs., vol. 12, 1918, p. 2519.

Discusses production and deposits, United States imports, and technology.

11. ———. Cobalt. Min. Ind., vol. 27, 1918, pp. 138–141; Chem. Abs., vol. 13, 1919, p. 2327.

Discusses the occurrence, production, and technology of cobalt, and includes a bibliography.

12. ———. Cobalt. Min. Ind., vol. 31, 1922, pp. 154–156; Chem. Abs., vol. 17, 1923, p. 3665.

Reviews production, metallurgy, and uses of cobalt, and gives a bibliography.

13. ———. Cobalt. Min. Ind., vol. 32, 1923, pp. 159–161; Chem. Abs., vol. 18, 1924, p. 3343.

Covers production, trade, and metallurgy.

14. ———. Cobalt: Its Production and Uses. Am. Electrochem. Soc. Advance Paper 27, for meeting May 7, 1923, pp. 357–363; Eng. Index, 1923, p. 162.

Reviews essential points in cobalt production.

15. ———. Cobalt. Min. Ind., vol. 33, 1924, pp. 164–167; Chem. Abs., vol. 19, 1925, p. 3452.

Metallurgy, uses, and production are treated.

16. ———. Cobalt. Min. Ind., vol. 34, 1925, pp. 177–180; Chem. Abs., vol. 20, 1926, p. 3674.

Discusses production, metallurgy, and uses.

17. Engineering. The Refinery of the Mond Nickel Co., Ltd., Clydach, South Wales. Vol. 130, No. 3375, Sept. 19, 1930, pp. 349–351; No. 3377, Oct. 3, 1930, pp. 422–425; and No. 3378, Oct. 10, 1930, pp. 454–456, 2 figs.; Eng. Index, 1930, p. 1202.

Sept. 19: Nickel ores, containing only 1 to 3 percent nickel, are treated in Canada near mines to free them of iron, rocky matter, and some sulfur. The ore is ground in ball mills to pass through 60-mesh sieves, then calcined to convert the nickel and copper sulfides into corresponding oxides.

Oct. 3: Reducers, volatilizers, and decomposers are discussed in connection with primary copper extraction.

Oct. 10: A study is made of the first nickel recovery, heating and reaction gases, and completion of the extraction process. Copper and nickel salts are discussed in connection with the extraction process.

18. Engineer and Mining Journal. Report of the Nickel Commission. Vol. 103, No. 15, Apr. 14, 1917, p. 679; Eng. Index, 1917, p. 266

The annual report contains information on mining and metallurgy of nickel.

19. Galibourg, Jean. [The Metallurgy of Nickel in Canada and the United States.] Rev. métal, vol. 24, 1927, pp. 627–645; Chem. Abs., vol. 22, 1928, p. 935.

Discusses the ore bodies, plants, and metallurgical processes of the International Nickel Co.

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20. GÉNIE CIVIL. La semaine du nickel. [The Nickel Week.] Vol. 91, No. 19, Nov. 5, 1927, pp. 462–468; Eng. Index, 1927, p. 568.

Abstracts papers on nickel metallurgy and nickel compounds.

21. GIBSON, T. W. Nickel. Min. Ind., vol. 31, 1922, pp. 486–498; Chem. Abs., vol. 17, 1923, p. 3665.

Discusses the metallurgy of nickel and world deposits, and gives production statistics.

22. ———. Nickel. Min. Ind., vol. 32, 1923, pp. 462–469; Chem. Abs., vol. 18, 1924, p. 3343.

World deposits, production, and metallurgy of nickel are discussed.

23. ———. Nickel. Min. Ind., vol. 33, 1924, pp. 506–514; Chem. Abs., vol. 19, 1925, p. 3451.

Metallurgy and production of nickel are treated.

24. ———. Nickel. Min. Ind., vol. 34, 1925, pp. 504–513; Chem. Abs., vol. 20, 1926, p. 3674.

Discusses deposits, uses, and metallurgy of nickel, and gives production statistics.

25. GUERREIRO, A. [Metallurgy of Nickel in Brazil.] Rev. Soc. brasil. chim., vol. 2, 1931, pp. 493–499; British Chem. Abs., 1932, p. 681B.

A new ore, termed "vilmite" (a nickel pyrites: Ni 75, Al 16–18, and S 7–9 percent) has been associated with pimelite in Aureliano Moura but is commercially unimportant. The concentrate from the matte process, which is difficult to separate from the slag, contains only 25 percent of Ni and 20 percent of S, also Ca, Si, etc. Mentions a new process that effects a fuel economy of 20–23 percent and yields a product containing 60–65 percent Ni, from which the slag (density 2.4) is easily removed.

26. GUILLET, M. [Nickel Week and Its Results.] La semaine du nickel, ses conséquences. Mém. Soc. ing. civils France, vol. 81, No. ½, January-February 1928, pp. 184–218, 33 figs.; Eng. Index, 1928, p. 1278.

Actual conditions of nickel metallurgy and pure nickel applications are discussed.

27. HIS MAJESTY'S STATIONERY OFFICE. Mineral Industry of the British Empire and Foreign Countries, 1919–21. Cobalt. 9 pp. Nickel. 20 pp.; Chem. Abs., vol. 18, 1924, p. 1454.

28. HYBINETTE, U. N. Development of Nickel-Refining Processes. Canadian Min. Jour., June 15, 1917; Eng. Index, 1917, p. 317.

29. JONES, A. R. R. The International Nickel Company of Canada, Ltd. Iron & Steel Canada, vol. 4, No. 10, November 1921, pp. 269–271; Eng. Index, 1922, p. 442.

Plant layout and operation are described.

30. LEONARD, R. W. The Mining and Metallurgy of Cobalt-Silver Ores. Jour. Eng. Inst. Canada, vol. 2, No. 2, February 1919, pp. 86–90; Eng. Index, 1919, p. 430.

Describes ore treatment in the districts of Timiskaming and northern Ontario.

31. LUND, R. J. Nickel and Cobalt. Bureau of Mines Minerals Yearbook, 1937, pp. 641–650; U. S. Pub. Doc. Cat., vol. 24, 1937–38, p. 590.

32. MASON, F. H. The Metallurgy of Nickel. Min. Sci. Press, Feb. 16, 1918, p. 233; Eng. Index, 1918, p. 331.

Nickel metallurgy is described in an abstract of a report of the Royal Ontario Nickel Commission.

33. MATHEWSON, E. P. Nickel. Address Before Royal Canadian Inst., Toronto; Canadian Min. Jour., Dec. 15, 1917; Eng. Index, 1918, p. 331.

An account is given of the production, extraction, and uses of nickel in Canada.

34. PARODI, L. [Note on the Metallurgy of Nickel.] Metallurg. ital., vol. 8, 1916, pp. 355–368; Chem. Abs., vol. 11, 1917, p. 1392.

Italian nickel, found chiefly in Valsesia and Recca Pietra, is roasted repeatedly and fused to get a concentrate of 40–50 percent Ni, Co, and Cu and 55–60 percent Fe and S. Treatment comprises seven operations, and the final product is nickel cubes and Co in the form of Co_2O_3. Only about half of the Ni and Co is extracted.

Nickel ore from New Caledonia, which occurs chiefly as garnierite, is fused with a substance capable of giving sulfur (usually soda with 15 percent S as $CaSO_4$). The melt contains 75 percent Ni and almost no iron. Roasting gives NiO, which is then reduced.

Pentlandite (NiFeS) occurs in basic stratum of nickel deposits from Sudbury, Ontario. Processing consists of incomplete roasting, fusing, and converter treatments. With this method and careful washing, the Canadian Copper Co. gets a rich matte containing Ni 40, Cu 44, and S 14 percent.

35. PERRAULT, R. Le cobalt: Gisements, préparation et emplois. Les gisements du Sud-Marocain. [Cobalt: Deposits, Preparation, and Uses. Deposits of South Morocco.] Génie civil, vol. 105, No. 11, Sept. 15, 1934, pp. 238–241; Eng. Index, 1934, p. 234.

Discusses the classification and treatment of cobalt ores and describes cobalt deposits in Germany, Canada, Belgian Congo, and Morocco.

36. QUENEAU, P. E. Metallurgical Improvements in the Treatment of Copper-Nickel Ores. Canadian Min. Met. Bull., vol. 41 (Trans., vol. 51), June 1948, pp. 356–367; Metals Rev., vol. 21, July 1948, p. 4.

Discusses improvements that have been introduced in recent years in the plants of the International Nickel Company of Canada, Ltd. Improvements include concentrating, smelting, and refining nickel and copper products.

37. REITLER, E. Verarbeifung griechischer Nickelerze in Deutschland. [Treatment of Greek Nickel Ores in Germany.] Metallbörse, vol. 20, No. 82, Oct. 11, 1930, pp. 2273–2274; Eng. Index, 1930, p. 1202.

Details of the treatment plant in Frankenstein are discussed, with emphasis on operating results and economic considerations. Smelting is done after the charge is briquetted.

38. RÉVUE GÉNÉRAL DE L'ÉLECTRICITÉ. Le Nickel, sa métallurgie et ses applications. [Nickel, Its Metallurgy and Its Applications.] Vol. 23, No. 10, Mar. 10, 1928, pp. 455–461; Eng. Index, 1928, p. 1279.

Gives a history of nickel metallurgy in New Caledonia and Canada.

39. SMITH, S. C. Treatment of Nickeliferous Materials (South African Copper-Nickel-Platinum Concentrates). U. S. Patent 1,770,866, July 15, 1930, appl., Apr. 18, 1929, United Kingdom, Apr. 18, 1928 (*see* British Patent 256,193, B, 1927, p. 449); British Chem. Abs., 1930, p. 823B.

40. VON SCHLICHTEN, O. C. Nickel and Cobalt. Min. Ind., vol. 25, 1916, pp. 523–531; Chem. Abs., vol. 11, 1917, p. 2874.

Discusses imports and exports, world production, technology, and the nickel industry in Canada.

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PRINCIPLES AND PROCESSES

41. BARCLAY, W. R. Cobalt and Its Uses. Jour. Soc. Chem. Ind., vol. 41, 1922, pp. 167–168R; Chem. Abs., vol. 16, 1922, p. 2102.

Barclay reviews our present knowledge of cobalt, with special reference to the work of H. T. Kalmus and his colleagues. Discusses briefly the sources and metallurgical treatment of Co, uses of Co oxides and salts, properties of metallic Co, Ni and Co, and cobalt alloys.

42. ——— Position of Nickel in Modern Metallurgy. Metal Ind. (London), vol. 30, 1927, pp. 25–29; Chem. Abs., vol. 21, 1927, p. 882.

43. BARWASSER, J. Neure Untersuchungen über die Reduktion von Nickel und Zinkerzen. [Reduction of Nickel and Zinc Ores.] Metal Ind. (London), vol. 30, No. 1, Jan. 7, 1927, pp. 25–29; Eng. Index, 1927, p. 568.

Summarizes the place of nickel in modern metallurgy and the nature and properties of its more important alloys.

44. BILLÓN, F. Cinc, estaño, niquel y cobalto. [Zinc, Tin, Nickel, and Cobalt.] Bailly-Baillieré, Madrid, 138 pp.; Chem. Abs., vol. 20, 1926, p. 1974.

45. BORCHERS, W. Nickel. Wilhelm Knapp, Halle an der Salle, Germany, 209 pp.; reviewed in Ztschr. Elektrochem., vol. 27, 1921, p. 375; Chem. Abs., vol. 16, 1922, p. 1206.

46. BORCHERS, W., AND PEDERSEN, H. Extracting Copper and Nickel From Low Grade Ores. U. S. Patent 1,043,291, Nov. 5, 1912; Chem. Abs., vol. 7, 1913, p. 61.

47. BRASS WORLD. The Nickel Industry. Vol. 6, pp. 438–439; Chem. Abs., vol. 5, 1911, p. 657.

Developments in the nickel industry are described.

48. BRIDGES, RALPH W. The Metallurgy of Canadian Cobalt Ores. Canadian Min. Jour., vol. 19, Jan. 15, 1916; Eng. Index, 1916, p. 322.

49. BULLETIN OF IMPERIAL INSTITUTE. The Occurrence and Utilization of Nickel Ores. Vol. 14, 1916, pp. 228–253; Chem. Abs., vol. 10, 1916, p. 3052.

Gives a history of the discovery of nickel and describes the occurrence of the ores in different countries and their metallurgical treatment.

50. CARON, M. H. Treating Nickel and Cobalt Ores. U. S. Patent 1,487,145, Mar. 18, 1924 (*see* Canadian Patent 283,734, Chem. Abs., vol. 18, 1924, p. 1268); Chem. Abs., vol. 18, 1924, p. 1975.

51. CHEMICAL INDUSTRY. Cobalt: Its Production and Some of Its Uses. Vol. 44, No. 8, Feb. 20, 1925, pp. 191–197; Eng. Index, 1925, p. 180.

52. CHEMICAL TRADE JOURNAL AND CHEMICAL ENGINEER. The Nickel Industry. Vol. 73, No. 1910, Dec. 28, 1923, pp. 767–768; Eng. Index, 1923, p. 467.

Discusses production, metallurgy, and uses of nickel, as taken from the introductory chapter to Monograph on Nickel Ores, by W. G. Rumbold.

53. CHEMISCHE FABRIK JOHANNISTHAL, G. M. B. H., AND TROSTLER, FRIEDRICH. [Recovery of Nickel and Copper.] French Patent 635,804, June 11, 1927 (*see* British Patent 283,132, Chem. Abs., vol. 22, 1928, p. 3847); Chem. Abs., vol. 22, 1928, p. 4391.

54. CORLESS, C. V. Research in Industry. Chem. Age (London), vol. 8, No. 209, June 16, 1923, pp. 646–647; Eng. Index, 1923, p. 467.

The director and manager of Mond Nickel Co., Canada, gives particulars of research carried out by the company, such as development of the Mond nickel process, uses of nickel, origin of carbonyl process, scope of scientific research, and development of research in the laboratories.

55. DENNIS, W. H. The Metallurgy of Cobalt. Min. Mag. (London), vol. 81, September 1949, pp. 144–146; October 1949, pp. 215–218; Metals Rev., vol. 22, December 1949, p. 26.

Discusses the extraction and uses of cobalt.

56. DYSON, G. M. The Extraction and Utilization of Cobalt. Chem. Age (London), vol. 19, No. 488, Nov. 3, 1928, pp. 33–35, 2 figs.; Eng. Index, 1928, p. 457.

Enumerates various methods of producing cobalt concentrates, and discusses processes for extracting cobalt and separating nickel and cobalt.

57. ESCARD, JEAN. [The Preparation in the Electric Furnace of Some Metals of Industrial Application.] Rev. gén. Élec., vol. 4, 1918, pp. 375–386; Chem. Abs., vol. 13, 1919, p. 930.

Gives a comprehensive discussion (with many working details) of the various methods of preparing metals and alloys of Ba, Ca, Be, Co, Ni, Ti, Mn, Cr, Mo, W, and V, with data on their chemical and physical properties and uses.

58. EUSTIS, F. A. Treating Nickel Ores. U. S. Patent 1,212,334, Jan. 16 (*see* British Patent 101,285, Chem. Abs., vol. 11, 1917, p. 31); Chem. Abs., vol. 11, 1917, p. 776.

59. FOURMENT, M., AND GUILLET, L. Métallurgie du plomb, du nickel, et du cobalt et alliages de ces métaux. [Metallurgy of Lead, Nickel, Cobalt, and Their Alloys.] J. B. Bailliere et fils, Paris, France, 492 pp.; reviewed in Chim. et ind., vol. 17, 1927, p. 174; Chem. Abs., vol. 21, 1927, p. 1093.

60. GANT, T. H. Cobalt: Its Production and Some of Its Uses. Chem. Ind., vol. 44, 1925, pp. 157–161, 191–197; Chem. Abs., vol. 19, 1925, p. 1328.

61. GRIFFITHS, W. T. Theory, Practice, and Nickel. Metal Ind. (London), vol. 34, Nos. 15–16, Apr. 12, 1929, pp. 363–365; Eng. Index, 1929, p. 1282.

Producing metallic nickel by the Mond carbonyl process is described.

62. GUILLET, LEON. Le Procédé Mond pour l'extraction du nickel. [The Mond Process for the Extraction of Nickel.] Génie civil, May 31, 1902; Eng. Index, 1901–5, p. 814.

A general account of the Mond process is given, with details of the apparatus.

63. ———. Le Nickel, sa métallurgie, et ses emplois. [Metallurgy and Uses of Nickel.] Génie civil, vol. 75, No. 20, 1919, pp. 473–481; No. 21, 1919, pp. 507–510; and No. 22, 1919, pp. 532–535; Eng. Index, 1920, p. 401.

Compares metallurgical practices at garnierite mines of New Caledonia and at mines of the Canadian Copper Co. The electrometallurgy of nickel by the wet process is also discussed.

64. ———. Le Nickel et ses applications. [Nickel and Its Applications.] Union ing. sortis écoles specials Louvain Bull. Tech., vol. 55, No. 2, Aug. 25, 1928, pp. 1–22; Eng. Index, 1928, p. 1278.

Discusses nickel metallurgy.

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65. GUILLET, LEON. [The Present Situation of the Metallurgy of Nickel.] Rev. métal., vol. 24, 1927, pp. 621–626; Chem. Abs., vol. 22, 1928, p. 935.

Discusses the history of nickel, its uses, and metallurgical treatments.

66. ———. La Métallurgie du nickel. [Metallurgy of Nickel.] Génie civil, vol. 52, No. 24, June 11, 1932, pp. 581–588; Eng. Index, 1932, p. 882.

Discusses modern methods of treating nickel ore and recovering precious metals from nickel ore, as developed by French, British, Canadian, and other mining companies.

67. GUILLET, L., AND WEILL, L. Le Nickel gisements, métallurgie, applications, perspectives d'avenir. [Nickel Deposits, Metallurgy Applications, and Prospects for the Future.] Génie civil, vol. 52, No. 20, May 14, 1932, pp. 482–490; No. 21, May 21, 1932, pp. 514–517; Eng. Index, 1932, p. 881.

68. INSTITUTE OF MARINE ENGINEERS. Contribution on "Mond Nickel." Trans., vol. 39, June 1927, pp. 254–259; Eng. Index, 1927, p. 569.

Gives a chart showing the various stages of production from nickel ore to well-known Mond nickel, the purest form of nickel produced commercially at the time.

69. LATHE, F. E. The Chemistry of the Hybinette Nickel Refining Process. Jour. Soc. Chem. Ind., vol. 44, 1925, pp. 433–438T, 443–444T; Chem. Abs., vol. 19, 1925, p. 3451; Eng. Index, 1925, p. 512.

Deals with roasting of matte, leaching, cementation of Cu on granulated unroasted matte, anode preparation, electrolysis for Ni, cathode melting, and making of malleable Ni.

70. LONEY, E. D. The Nickel Industry; Some Further History. Canadian Min. Jour., vol. 50, No. 3, Jan. 18, 1929, pp. 50–52, 3 figs.; Eng. Index, 1929, p. 1281.

History of nickel mining has been largely concerned with developing uses for the metal. Discusses mining progress and metallurgical development in the Sudbury district.

71. MATHEWSON, E. P. History of the Nickel Industry Since 1910. Jour. Soc. Chem. Ind., vol. 37, 1918, p. 53T; Chem. Abs., vol. 12, 1918, p. 1039.

72. MERICA, PAUL D. Notes on Nickel. Chem. Met. Eng., vol. 24, No. 1, Jan. 5, 1921, pp. 17–21; Eng. Index, 1921, p. 374; Chem. Abs. vol. 15, 1921, p. 653.

Brief notes on metallurgy of nickel.

73. METAL INDUSTRY (LONDON). Nickel Refining in South Wales. Vol. 20, No. 7, Feb. 17, 1922, pp. 147–151; Eng. Index, 1922, p. 442.

Describes the works of the Mond Nickel Co., Ltd., at Clydach, Swansea, and the Mond process.

74. MOND, LUDWIG. The History of Mond's Nickel Extraction Process. Eng. Min. Jour., vol. 60, No. 2, Nov. 16, 1895, p. 464; Eng. Index, 1896–1900, p. 669.

Abstracts a paper read before the New York section of the Society of Chemical Industry, giving results of experiments that led to treating nickel with CO gas.

75. NATIONAL BUREAU OF STANDARDS. Nickel and Its Alloys. Circ. 100, 2d ed. revised May 9, 1924, 162 pp.; U. S. Pub. Doc. Cat., vol. 17, July 1, 1923, to June 30, 1925, p. 1503.

76. SULMAN, H. L., AND PICARD, H. F. K. Extracting Nickel. British Patent 27,626, Nov. 30, 1912 (*see* U. S. Patent 1,091,545); Chem. Abs., vol. 8, 1914, p. 1733.

77. ———. Nickel From Ore. U. S. Patent 1,193,734, Aug. 8, 1916 (*see* British Patent 17,131, Chem. Abs., vol. 9, p. 289); Chem. Abs., vol. 10, 1916, p. 2347.

78. TYLER, P. M. Cobalt. Bureau of Mines Inf. Circ. 6331, 1930, 33 pp. (*see* Canadian Min. Jour., vol. 51, No. 40, Oct. 3, 1930, pp. 936–938, 957–958, 2 figs.; Eng. Index, 1930, p. 400.

Metallurgical processes used in the production of cobalt are described.

79. ULKE, TITUS. The Mining, Smelting, and Refining of Nickel. Eng. Mag., vol. 161, December 1898, p. 511; Eng. Index, 1896–1900, p. 669.

Gives a detailed account of processes used in various places, also data on cost with special reference to electrolytic refining methods and the saving of valuable byproducts.

80. ———. Progress in the Metallurgy of Nickel During 1902. Eng. Min. Jour., Apr. 25, 1903; Eng. Index, 1901–5, p. 814.

Describes developments in various districts and processes used.

81. VOLTA, H. Le Nickel et la guerre. [Nickel and the War.] La Nature, Aug. 5, 1916; Eng. Index, 1916, p. 269.

Methods of mining and smelting nickel are reviewed.

82. WADHAMS, A. J. The Year's Progress in the Nickel Industry and the Outlook for 1929. Metal Ind., vol. 27, No. 1, January 1929, pp. 13–14; Eng. Index, 1929, p. 1281.

Discusses improved smelting and refining methods.

83. ———. Nickel Industry. Metal Progress, vol. 19, No. 3, March 1931, pp. 92–98, 5 figs.; Eng. Index, 1931, p. 959.

Outlines all phases of the industry, including mining, smelting, and refining.

84. WALLACE, GEORGE L. Observations on Nickel Mining in Canada and Its Relation to the Manufacture of Nickel Anodes. Brass World, October 1911; Eng. Index, 1911, p. 407.

Describes different operations through which nickel ore passes before it is ready for casting into commercial nickel anodes.

85. WALTER, H. W. Nickel. Canadian Chem. and Met., vol. 15, No. 7, 1931, pp. 185–191, 194, 4 figs.; Eng. Index, 1931, p. 959.

Describes smelting operations at Copper Cliff, refining nickel from Bessemer matte, also the Orford, Mond, and Hybinette processes.

OXIDIZED ORES

86. CONTAL, R. [Nickel in New Caledonia.] Rev. métal, vol. 24, 1927, pp. 646–653; Chem. Abs., vol. 22, 1928, p. 935.

Outlines the development of the nickel industry in New Caledonia, nature of the deposits, methods of working them, and metallurgical processes.

87. DAVIS, C. W. Treatment of Low-Grade Nickel Ores. Jour. Ind. Eng. Chem., vol. 11, 1919, pp. 644–648; Chem. Abs., vol. 13, 1919, p. 1811.

Investigation of low-grade nickel ore (silicate) from North Carolina, containing a high percentage of iron, showed it could not be profitably treated at the time. Low-grade silicate ore with low percentage of iron might be economically treated by roasting, reduction, roasting with niter cake, water extraction, or precipitation with CaO; also, it can be treated with HNO_3. The commercial applicability of the first process depends on the price of niter cake and the complexity

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of the process; that of the second depends upon the percentage of HNO_3 recovered.

88. Ghislain de Burlet, L. J. [Cobalt or Nickel in Metallic Form From Their Artificial or Natural Silicates.] German Patent 291,505, Nov. 26, 1913 (*see* Chem. Abs., vol. 9, p. 1279); Chem. Abs., vol. 11, 1917, p. 573.

89. Koehler, William. Recovery of Nickel From Oxide and Silicate Ores. Elec. Chem. Met. Ind., April 1908; Eng. Index, 1908, p. 347.

Describes a process for handling ores not readily amenable to smelting methods.

NONOXIDIZED ORES

90. Borchers, W. Obtaining Nickel and Copper From Sulfide Ores. U. S. Patent 1,101,115, June 23, 1914 (*see* Chem. Abs., vol. 7, 1913, p. 3309); Chem. Abs., vol. 8, 1914, p. 2866.

91. McKechnie, A., and Beasley, F. G. Nickel-Copper Mattes. Canadian Patent 143,074, Oct. 1, 1912; Chem. Abs., vol. 7, 1913, p. 32.

Gives a process of treating nickel-copper mattes.

92. McLarty, James A. Treatment of Nickel Sulfide Ores. Canadian Patent 131,817, Mar. 21, 1911; Chem. Abs., vol. 5, 1911, p. 1903.

Nickel sulfide ores are demagnetized and passed through a magnetic separator.

93. Srednik, Y. Y. [Tests With a View to Obtaining Copper-Nickel Mattes in the Urals.] Comm. trav. tech. sci. Rep. Russie, vol. 5, 1921, p. 124; Rev. Métal, vol. 19, p. 568; Chem. Abs., vol. 17, 1923, p. 519.

In 1916, the Revdinsky works began a study of the utilization of Ni (0.86 percent) and Cu (1.5 percent) ores, with the ultimate aim of finding if it would be possible to treat them electrolytically and more immediately to produce a Cu–Ni matte. A special crucible furnace having a section of 1 m. × 1 m. and a height of 10 m. was constructed, in which was treated a total of 130 tons of ore and flux. Wood charcoal proved unsatisfactory. With coke, the matte could be satisfactorily separated from the slag, which held back traces of Ni and 0.12–0.23 percent Cu. The matte contained 2.81 percent Cu and 1.13 percent Ni. The ratio of nickel ore to copper pyrites was gradually increased to 1:1.2. The final charge comprised copper pyrites 270, nickel ore 330, slag from reheating furnace 220, CaO 80, and coke 125 kg. The test was considered successful.

94. Stanley, R. C. Nickel and Copper From Mattes, etc. British Patent 240,789, Sept. 30, 1924; (*see* U. S. Patent 1,533,197, Chem. Abs., vol. 19, 1925, p. 3473); Chem. Abs. vol. 20, 1926, p. 2144.

95. Wells, H. L. Process of Extracting Nickel From Matte With Hydrochloric Acid. U. S. Patent 1,044,316, Nov. 12, 1912; Chem. Abs., vol. 7, 1913, p. 62.

INTEGRATED SEQUENCES OF OPERATIONS

NONSPECIFIED ORES

96. Bridges, R. W. Metallurgy of the Ores From Cobalt, Ontario. Canadian Min. Jour., vol. 19, Jan. 15, 1916; Eng. Min. Jour., vol. 101, 1916, pp. 646–647; Chem. Abs., vol. 10, 1916, p. 1316.

Nickel ore was crushed to minus-30-mesh and treated in 32- by 72-inch blast furnaces, using Michigan limestone as a basic flux and low-grade Crown Reserve ore as an acid flux. The resultant speiss was ground in a ball mill to 30-mesh, 20 percent of NaCl being added as the speiss was charged to the mill. This high-iron speiss was roasted and transferred to the hypo-leaching building where it was treated in a large agitation cylinder, first with cold water to dissolve out the undecomposed NaCl and the soluble salts of Co, Ni, and Cu. This water solution was decanted onto scrap iron to precipitate the Cu and then pumped to another tank, where the Co and Ni were precipitated as hydroxides by NaOH. This precipitate was dried, calcined to oxides, ground, and barreled for shipment.

97. Caron, M. H. Recovering Values From Nickel and Cobalt-Nickel Ores. Canadian Patent 238,734, Mar. 18, 1924; Chem. Abs., vol. 18, 1924, p. 1268.

Nickel and cobalt ores are given a reducing roast, cooled in a nonoxidizing atmosphere, and treated with NH_3 salt solutions to extract the Ni and Co, which are recovered; the NH_3 compounds are reused.

98. Eustis, F. A., Treating Nickel Ores. British Patent 101,285, June 28, 1916; Chem. Abs., vol. 11, 1917, p. 31.

In treating Ni ores containing other metals, such as Fe, Mn, Al, and Cr, particularly for the recovery of the Ni or Ni, Al, and Mn, the ore is roasted with a small proportion of sulfur-bearing material, preferably at about 460° C. for about 4 hours or about 500° C. for 15 to 30 minutes; or it is moistened with H_2SO_4 and roasted at about 500° C. for a few hours, yielding a product containing a relatively large amount of soluble Ni and a relatively small amount of soluble Fe. The product is leached, preferably with hot dilute H_2SO_4 or a mixture of dilute H_2SO_4 and HCl, and the resulting solution is treated with a base, preferably with limestone contained in a revolving drum immersed in the bath. When the acid is neutralized, the solution is treated in a separate vessel with fresh base to precipitate the $Al(OH)_3$ and, if desired, in another vessel to precipitate the Fe. The solution, after suitable concentration, may be electrolyzed; or the Ni may be precipitated in a separate vessel, preferably by soda ash, the precipitate being redissolved and electrolyzed; Mn, if present, is obtained at the anode as dioxide.

99. Lance, R. Extracting Zinc, Copper, Cadmium, Cobalt, Nickel, or Other Metals From Ores. U. S. Patent 1,247,413, Nov. 20, 1918; Chem. Abs., vol. 12, 1918, p. 272.

Ores that may contain sulfides, oxides, silicates, or other compounds are sulfatized and leached, and the resulting sulfate solution is treated with $CaCl_2$ or NaCl to obtain a solution of the metal as chloride; the solution, in turn, may be treated with $3CaO \cdot CaCl_2$. If desired, the ore may be chloridized directly without being sulfatized.

100. Pecourt and Faillet. [Extraction of Cobalt From Its Minerals.] French Patent 403,830, June 9, 1909; Chem. Abs., vol. 4, 1910, p. 1867.

In extracting cobalt from its minerals, especially manganiferous cobalt minerals, the ore is mixed with FeS, treated with H_2SO_4, then heated to a cherry red; $2FeS_2 + 15MnO_2 = Fe_2O_3 + 4MnSO_4 + 11MnO$; $NiSO_4$, $Fe(OH)SO_4$, and $CoSO_4$ are formed. For a mineral containing 25 percent of Mn as MnO_2, and 4 percent of Co and 2 percent of Ni as oxides, 40 percent of the weight of the dry mineral is mixed with H_2SO_4 at 53° B. and 7 percent FeS_2. The roasted mass is washed; the basic sulfates remain insoluble and the Co, Ni, and Mn dissolve. The solution is heated to boiling, $CaCO_3$ is added, and Fe is precipitated. Calcium chloride is

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added to transform Mn, Ni, and Co into chlorides, and the Ni and Co are precipitated by CaS, the Mn remaining in solution. After filtration the Mn is precipitated by CaO. The NiS and CoS are decomposed by dilute H_2SO_4 to remove the little MnS which remains. These sulfides are calcined, and the resulting sulfates are dissolved by oxidizing the solution with hypochlorite. After the liquid has been made alkaline it is made weakly acid, the Co precipitating as sesquioxide and the Ni remaining in solution as sulfate.

101. SEIGLE, ADOLPHE. Extraction of Gold, Platinum, Silver, Nickel, Copper, Etc. U. S. Patent 915,705, Mar. 16, 1909; Chem. Abs., vol. 3, 1909, p. 1392.

Gold, platinum, copper, silver, nickel, etc., are extracted from ores, tailings, and other residues or wastes by roasting and pulverizing. Mixing the ore or waste with finely divided siliceous material, treating it with a solution of $CaCl_2$, NaCl, $MgCl_2$, $SrCl_2$, or $FeCl_2$ and steam under pressure, and finely washing the product extracts the chlorides of the metals.

102. UDY, M. J. Cobalt From Ores. U. S. Patent 1,336,765, Apr. 13, 1920; Chem. Abs., vol. 14, 1920, p. 1643.

Ore such as a cobalt ore containing arsenic is subjected to a sulfatizing roast with H_2SO_4; soluble sulfates are extracted with water, then $CaCO_3$ is added as a precipitating agent in the presence of air. Copper is removed from the solution by the action of As, and barely enough lime is added to the solution to form a basic insoluble sulfate. A bath containing cobalt sulfate is electrolyzed with an insoluble anode, and the basic sulfate is dissolved in the electrolyte in proportion to the rise in acidity of the electrolyte. Thus, the acidity of the electrolyte is maintained at 0.3 to 1.0 percent.

OXIDIZED ORES

103. ANNABLE, H. W. C., AND NICKEL CONCENTRATION, LTD. Extracting Nickel. British Patent 125,119, May 27, 1916; Chem. Abs., vol. 13, 1919, p. 1705; U. S. Patent 1,289,072, Dec. 31, 1919.

Silicate ores of Ni, such as garnierite, are heated in a furnace in the presence of moist H_2S and, preferably, a small quantity of a Na or K salt. Suitable salts for this purpose are NaCl, which may be used in the form of sea water, Na_2CO_3, Na_2SO_4, and the corresponding salts of K. The process is preferably carried out by mixing the ore with a S-bearing substance, such as iron pyrites or copper pyrites, adding a small quantity of a Na or K salt, and heating the mixture in a furnace through which a current of steam is passed; with a carbonate salt, sulfur may be used instead of pyrites. The resulting mass contains nickel sulfide, which is converted into nickel sulfate. The hot mass is discharged into water to dissolve out the nickel sulfate; sometimes, during the roast a basic sulfate of Ni is formed which may be dissolved by adding HCl to the water. Nickel may be precipitated as carbonate by adding magnesite or as sulfide by adding Na_2S.

104. DE BURLET, L. J. G. Extracting Cobalt or Nickel From the Natural Silicates: British Patent 27,150, Nov. 25, 1913; Chem. Abs., vol. 9, 1915, p. 1279.

A process for extracting cobalt or nickel from the natural silicates consists of fusing the material to extract most of the copper. After comminuting the residue and treating it with dilute H_2SO_4, a pasty mass is formed, which is dried in a current of air at 150°–200° C. The dry mass is treated with hot water and filtered, and $CaCO_3$ is added to the liquid. Iron and most of the copper precipitates; the remaining copper is removed by electrolysis. The solution is treated with NH_3 to obtain an ammonia-cobalt or nickel compound, from which the Co or Ni is finally removed by electrolysis.

105. HAYWARD, C. R. Extraction of Nickel and Alumina From Cuban Iron Ores. Chem. Met. Eng., vol. 26, 1922, pp. 261–266; Chem. Abs., vol. 16, 1922, p. 1380.

Describes a method for sulfatizing and leaching Cuban ores that will profitably extract 70 percent of the Ni, 50 percent of the Al_2O_3, and 60 percent of the Mn, leaving a beneficiated iron ore and yielding gypsum and iron oxide pigment as byproducts. This process is conducted in nine steps, each described briefly below. (1) Hydraulically mined ore is riffled to recover most of the chromite. (2) A sulfatizing roast is conducted in a SO_2 atmosphere. (3) Leaching is performed in an agitation tank in the presence of scrap iron to reduce iron in solution to the ferrous state. (4) The cake is filtered and washed, and (5) $CaCl_2$ is added to the leach liquor to precipitate sulfates as gypsum. Remaining steps include: (6) Agitation with limestone; (7) aeration and filtration to separate $Fe(OH)_2$; and (8) precipitation of Ni and Mn with burnt lime, leaving a solution to be concentrated by evaporation and returned to the gypsum precipitation for further treatment. (9) Finally, Ni and Mn products are fused to produce pig nickel or dissolved in H_2SO_4 and electrolyzed, giving pure Ni cathodes and MnO_2 at the anodes.

106. HAYWARD, C. R., SCHLEICHER, H. M., AND STILLMAN, F. O. U. S. Patent 1,370,646, Mar. 8, 1921; Chem. Abs., vol. 15, 1921, p. 1876.

Ore such as soft Cuban iron ore containing Ni, Mn, and Cr is dried, preheated, and subjected to a sulfatizing roast regulated to convert as much of the Ni and Al as possible into soluble sulfates and render soluble a portion of the Mn and Cr. The roasted material is treated to remove gypsum and ferric iron. The solution, which still contains Ni and Mn, is treated with CaO to precipitate hydroxides of Mn and Ni; these are separated and washed. Nickel is recovered by electrolytic refining.

107. KOEHLER, WILLIAM. Recovery of Nickel From Oxide and Silicate Ores. Electrochem. Met. Ind., vol. 6, 1908, pp. 145–147; Chem. Abs., vol. 2, 1908, p. 1817.

Nickel silicate ore is leached with a concentrated solution of ferric sulfate, which brings the manganese, nickel, and cobalt into solution and leaves the iron behind as oxide. Cobalt, nickel, and a small amount of manganese are precipitated by sodium sulfide, and the sulfides are roasted to sulfates. The sulfates are dissolved in hot water and converted into chlorides by calcium chloride. In one-half the solution the cobalt and nickel are precipitated as oxides by lime and converted into sesquioxides by chlorine and an air blast. This precipitate is added to the other half of the solution. The cobalt remains in solution, and the nickel is precipitated as oxide when milk of lime is added. The process is applicable only to a Le Blanc soda works.

108. MOA IRON & DEVELOPMENT CORPORATION. Treating Iron Ores; Obtaining Nickel. British Patent 155,246, Nov. 30, 1930; Chem. Abs., vol. 15, 1921, p. 1131.

Soft iron ores from north Cuba, which contain oxides and/or silicates of Al and Fe and small quantities of Ni, Mn, and Cr, are treated to yield a solution of the sulfates of Al and other metals, leaving a residue of purified iron ore. The sulfate solution is treated with $CaCl_2$ to convert the sulfates into chlorides and then treated with $CaCO_3$ to precipitate Al, Fe^{III}, and Cr. The precipitate is treated to recover Al_2O_3 and Cr, and air and $CaCO_3$ are added to oxidize the remaining Fe and precipitate it as $Fe(OH)_3$. The filtrate is treated with CaO to precipitate nickel and manganese hydroxides. The precipitate is washed and dissolved in H_2SO_4,

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then the solution is electrolyzed with an insoluble anode and a nickel cathode to obtain metallic nickel and manganese oxide.

109. WARLIMONT, FELIX. [Process for the Treatment of Copper and Nickel Bearing Magnetites.] Métallurgie, vol. 6, pp. 127–134; Chem. Abs., vol. 4, 1910, p. 1964.

The author suggests a process of treating the ore by roasting and leaching it and converting the residue into nickel regulus. The nickel concentrates are treated to remove pure Ni.

NONOXIDIZED ORES

110. BORCHERS, W. Extracting Nickel and Copper From Ores. British Patent 227, Jan. 3, 1912; Chem. Abs., vol. 7, 1913, p. 2039.

In a process for extracting nickel and copper from ores or byproducts containing sulfides of these metals and iron, the ore is smelted with or without a flux to yield a matte and a slag almost free of Cu and Ni. The matte is roasted at about 600° C. to convert most of the Cu and Ni into sulfates and the Fe into oxide. The roasted product is leached with acidulated water, and the residue from the leaching is used as a flux in the first smelting. The sulfate solution is treated with calcium or sodium sulfide to precipitate first the Cu then the Ni. The precipitated sulfides are smelted separately with lime or limestone and carbonaceous material to obtain pure Cu and Ni. The slag contains chiefly CaS, which may be used as a precipitate for the copper and nickel sulfate solution or to obtain Na_2S, which is used as the precipitant.

111. DIEDENHOFEN, G. [Blast Roasting of Speiss With Ferrous Chloride.] Metall. u. Erz, vol. 20, 1923, p. 425; Chem. Abs., vol. 18, 1924, p. 2117.

If a mixture of finely ground speiss and $FeCl_2$ solution, dried and broken in large lumps, is placed in a converter through which air heated to 170° C. is passed, a vigorous reaction results with the evolution of fumes of arsenic and antimony chlorides. Once begun, the action proceeds rapidly to completion even if cold air is passed through the mass. By leaching the residue with a hot 0.4-percent solution of HCl, over 90 percent of the Cu, Ni, and Pb are dissolved. The Pb may be separated by adding enough H_2SO_4 to convert all of the metals into sulfates. Copper is precipitated on scrap iron, and the nickel in the filtrate is separated as a double salt by the addition of $(NH_4)_2SO_4$. The final liquor contains $FeCl_2$ and may be used again in the process.

112. FAIRWEATHER, H. G. C. Treating Copper-Nickel Solutions. British Patent 185,859, June 15, 1921; Chem. Abs., vol. 17, 1923, p. 257.

Bessemerized Cu-Ni matte may be ground, roasted, and leached with H_2SO_4. Part of the leached residue is reduced to metal and used in excess as a precipitant for the solution obtained from the remainder of the leached residue. The solution is precipitated at normal temperatures, preferably on the countercurrent principle.

113. GALIBOURG, J. AND CONTAL, R. Résumé de la situation actualle de l'industrie du nickel an Canada, aux États-Unis et en Nouvelle Caledonie. [Summary of the Actual State of the Nickel Industry in Canada, United States, and New Caledonia.] Rev. univ. mines, vol. 17, No. 5, Mar. 1, 1928, pp. 233–241; Eng. Index, 1928, p. 1279.

Describes metallurgy of nickel, treatment of fines, and refining of nickel matte by processes used in Canada, the United States, and New Caledonia.

114. HADDAN, R. Metallurgy of Arsenical Ores. British Patent 190,025, Jan. 3, 1922; Chem. Abs., vol. 16, 1923, p. 2860.

Arsenical ores and materials, more particularly arsenical Co and Ni ores, are chlorinated at 400°–600° C. to remove As and Fe without volatilizing the chlorides of Co, Ni, and Ag. The solid residue delivered from the chlorination chamber, which may contain Co, Cu, Ni, and Ag chlorides, is leached with about eight parts of water; the dissolved chlorides are separated and recovered in any convenient way.

115. HAGLUND, G. Treating Matte. British Patent 158,887, Feb. 7, 1921; Chem. Abs., vol. 15, 1921, p. 1879.

Ni and Cu matte is converted until most of the Ni is reduced to metal. Part of the matte is treated with acid in the presence of air; Cu is precipitated from the solution using another part of the matte, and Ni is recovered from the remaining solution. The undissolved residues of the dissolving and cementation processes are roasted; the resulting Cu and Ni oxides are leached with acid, the undissolved oxides reduced to metal, and the precious metals recovered. The metal reduced from the undissolved oxides may be used instead of matte for precipitating the Cu-Ni solution in the earlier stage of the process, or the part of the matte used for precipitation may be converted further than that treated with acid.

116. ———. Treating Copper-Nickel Sulfides. Swedish Patent 53,970, Mar. 7, 1923; Chem. Abs., vol. 18, 1924, p. 2491.

The sulfides are converted until most of the nickel is transformed into metal. Then part of the material is treated with acid and air, and the solution is cemented with another part of the converted materials to produce a Cu-free solution of Ni. The residue from the acid treatment is roasted with the residue from the cementation. The oxides of Cu and Ni thus obtained are treated with dilute acid to dissolve most of the Cu. The undissolved oxides are reduced to metal. The precious metals are recovered from the anode slime.

117. JOHNSON, W. McA. Treating Ore Containing Silver, Nickel, and Arsenic. U. S. Patent 1,107,310, Aug. 18, 1914; Chem. Abs., vol. 8, 1914, p. 3287.

Treating ore containing silver, nickel, and arsenic with moist Cl_2 in a closed vessel at a temperature of about 350° C. converts the As into $AsCl_3$, which vaporizes, freeing the ore from As. Leaching the residue with dilute HCl dissolves the Co and Ni, and the Ag is recovered from the residue after leaching by treatment with KCN and electrolyzing. The Co and Ni are separated by treatment with $CaOCl_2$ or Cl_2 and Na_2CO_3.

BENEFICIATION OF MATERIALS

ORE DRESSING, NONSPECIFIED ORES

118. DAVIS, C. W. Treatment of Low-Grade Nickel Ores. Jour. Ind. Eng. Chem., vol. 11, No. 7, July 1, 1919, pp. 644–648; Eng. Index, 1919, p. 322.

No satisfactory concentration of ores was obtained by sizing tests, panning, tabling, magnetic concentration, or flotation. Magnetic treatment of reduced North Carolina ore raised concentration of nickel from 0.97 percent to 3.6; recovery was 45 percent.

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119. ENGINEERING AND MINING JOURNAL. Experimental Treatment of Complex Ore. Vol. 107, 1919, p. 913; Chem. Abs., vol. 13, 1919, p. 1575.

Ore containing MoS_2, MoO_3, Co, Ni, As, and Au is crushed in a wet ball mill in circuit with a classifier to about 40-mesh. Concentration is accomplished best on Wilfley-type tables. The tailings are reground in a ball or tube mill to 100-mesh in circuit with the classifier. Molybdenite is floated in an oil-flotation unit, and the tailings are concentrated on slime tables or vanners.

120. GODARD, J. S. Experimental Flotation Tests on Cobalt Ore From Yorkshire Cobalt Mines, Ltd., Cobalt, Ontario. Canadian Dept. Mines Mines Branch Rept. 724, 1932, pp. 160–163; Eng. Index, 1932, pp. 160–163, 272.

Grinding the ore to minus-100-mesh with 75 percent minus-200-mesh is considered good practice. Flotation tests on two samples yielded 78 and 83 percent of cobalt.

121. MAY, WALTER J. The Treatment of Cobalt and Other Similar Ores. Coll. Guard., vol 76, Nov. 25, 1898, p. 970; Eng. Index, 1896–1900, p. 189.

Gives suggestions for economical treatment of ore, particularly in classification.

122. WATSON, R. B. Notes on Metallurgy at Cobalt During 1916. Canadian Min. Jour., vol 20, Mar. 1, 1917; Eng. Index, 1917, p. 313.

Flotation processes are discussed.

123. WELLS, R. R., SANDELL, W. G., SNEDDEN, H. D., AND MITCHELL, T. F. Concentration of Copper-Cobalt Ores From the Blackbird District, Lemhi County, Idaho. Bureau of Mines Rept. of Investigations 4279, 1948, 21 pp., Metals Rev., vol. 21, August 1948, p. 4.

Results of laboratory and small-scale pilot-plant investigations of beneficiation are described.

ORE DRESSING, NONOXIDIZED ORES

124. HALFERDAHL, A. C. Flotation Test on a Copper-Nickel Ore. Canadian Min. Jour., vol. 48, 1927, pp. 608–609; Chem. Abs., vol. 21, 1927, p. 3865.

Attempts were made to float copper and nickel selectively from pyrrhotite in a Manitoba ore, aided in some tests by magnetic separation. Nickel and copper were separated from pyrrhotite only at meshes finer than 200. It was impossible to make a high Ni concentrate without grinding the ore to slime.

125. VEIL, SUZANNE. [The Evolution of Nickel and Cobalt Sulfides in Water.] Compt. rend., vol. 186, 1928, pp. 80–81 (*see* Chem. Abs., vol. 21, 1927, p. 1218); Chem. Abs., vol. 22, 1928, p. 1091.

Nickel sulfide, prepared in the cold, is less magnetic than $Ni(OH)_2$ likewise prepared. After NiS has remained in warm water it is less easily oxidized and less magnetic. Calcination of both NiS and $Ni(OH)_2$ produces oxides that are alike magnetically. Results were similar using cobalt.

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PART II. PYROMETALLURGICAL

PYRO TREATMENTS, GENERAL

REDUCTION TO METAL

126. CARRICK, JAMES T. (assigned to Basil S. Pattison, Johannesburg, Transvaal). Smelting Copper or Copper-Nickel Ores. U. S. Patent 913,655, Feb. 23, 1909; Chem. Abs., vol. 3, 1909, p. 1003.

Gaseous or finely divided solid fuel is burned in a reverberatory furnace, the draft being checked to allow flame or heated gas to issue with the smelting products and prevent access of cold air.

127. DOWNIE, C. C. Present Day Blasting of Nickel. Metal Ind. (London), vol. 45, No. 9, Aug. 31, 1934, pp. 195–197; Eng. Index, 1934, p. 743.

Discusses briquetting, blast-furnace operations, and supplementary processes.

128. GARRED, U. A. Smelting. U. S. Patent 1,311,807, July 29, 1919; Chem. Abs., vol. 13, 1919, p. 2503.

Ore to be smelted is arranged in a vertical pile in a shaft furnace. Pulverized fuel in a space adjoining the lower part of the pile forces the ignited stream against the pile and melts the ore. This fuel is in addition to that in interstices between the ore particles. The method is well adapted to smelting Cu, Ni, or Fe ores.

129. HYBINETTE, NOAK V. [Separate Recovery of Copper and Nickel by Roasting.] German Patent 200,372, Nov. 28, 1905; Chem. Abs., vol. 2, 1908, p. 3055.

The roasted ore is extracted with dilute H_2SO_4, roasted with strong H_2SO_4, and again extracted with dilute H_2SO_4. The residue is heated with HCl to form $CuCl_2$, which is separated by lixiviation. The residue from this treatment consists of nickelous oxide, which is reduced in the known manner.

130. KALMUS, H. T. Preparation of Metallic Cobalt by Reduction of Oxide. Canadian Dept. Mines, No. 259, 36 pp.; Eng. Index, 1914, p. 454.

Describes research conducted at the School of Mines, Queens University, Kingston, Ontario.

131. KOSTER, J., KNICKERBOCKER, R. G., GARST, O. C., EVANS, T. E., AND CODY, W. E. Progress Report—Metallurgical Division. 35. Electrometallurgical Investigations. Recovery of Nickel, Copper, and Precious Metals From Domestic Ores by Combined Electrothermal and Electrolytic Method. Bureau of Mines Rept. of Investigation 3483, 1940, 28 pp.; U. S. Pub. Doc. Cat., vol. 25, Jan. 1, 1939, to Dec. 31, 1940, p. 1509.

132. MIRONOV, A. A. [Production of Metallic Nickel From Ufaley Nickel Ores.] Tsvetnye Metal., No. 1, January 1930, pp. 48–67, 8 figs.; Eng. Index, 1930, p. 1202.

Gives an account of experimental runs made at the Sverdlovsk plant, following the general scheme of Frankenstein nickel smelters in Germany, as modified by N. N. Baraboshking.

133. MORRISON, W. L. Electric Furnace Treatment of Nickel Ore and the Development of a Commercial Process. Trans. Am. Electrochem. Soc., vol. 20, 1912, p. 312; Chem Abs., vol. 6, 1912, p. 29.

Discusses a process for treating, low-grade Ni ores containing about 1.75 percent oxide and large percentages of SiO_2 and Al_2O_3. CO reduction and C reduction with magnetic separation and wet methods failed. An electric furnace similar to the Héroult furnace at Sault Ste. Marie was used. The records of runs show 9,000 pounds of ore treated per kilowatt-year, with 1,380 pounds of silicide obtained. This silicide contains 10 to 22 percent Ni. The output per day has been 800 to 1,200 pounds of silicide, with an operating cost of $148.80. The paper closes with a discussion of various furnace designs and a proposed improved electric smelter.

134. SOCIÉTÉ ÉLECTROMÉTALLURGIQUE FRANCAISE. [Pure Nickel.] French Patent 400,910, June 27, 1908; Chem. Abs., vol. 4, 1910, p. 1866.

Pure nickel is produced by blowing nickel melt (made by the process covered by French Patent 336,376, Oct. 30, 1903) in a Bessemer furnace or by pulverizing the melt in a jet of air and treating it in a reverberatory or muffle furnace. Treatment in the furnace should be such that the slag always contains a trace of NiO.

ROASTING WITH A SALT OR SALT-FORMING GAS

135. ASHCROFT, E. A. Treatment of Ores, Etc., Containing Copper and Nickel. British Patent 338,556, Aug. 8, Sept. 9, and Nov. 25, 1929, and Apr. 12, 1930; British Chem. Abs., 1931, p. 120B.

Nickel or copper ore, which may be oxidized or sulfidic, is mixed, if necessary, with a sulfide ore of the same metals or of iron, and the mixture is treated at 400° C. with a current of oxygen or air enriched with oxygen. The gas stream is regulated so that the temperature of the mass, which is not rabbled or otherwise disturbed, remains about 600° C. Ferrous chloride or sulfate may be used instead of sulfide ores with oxidized copper or nickel ores. The roasted product is leached with water, which dissolves most of the copper and nickel and gives a neutral sulfate solution almost free from iron; treating this solution with ammonia provides ammonium sulfate and nickel and copper oxides.

136. BREMHORST, A. Darstellung metallischen Kobalts aus kobalthaltigen Hüttenrückstanden. [Obtaining Metallic Cobalt From Mine Refuse.] Metall. u. Erz, vol. 24, No. 1, Jan. 1, 1927, pp. 7–8; Eng. Index, 1927, p. 209.

After many experiments the author developed a dry concentrating process, involving roasting the ore with sodium sulfate and carbon, whereby he obtained metallic masses containing 91 to 94 percent cobalt instead of the 0.5 to 5 percent found in the original refuse material.

137. D'ADRIAN, A. L. D. Extracting Chromium, Zirconium, Vanadium, Uranium, Cobalt, Silver, or Nickel From Ores. Canadian Patent 229,726, Mar. 20, 1923; Chem. Abs., vol. 17, 1923, p. 1948.

The finely divided metal is treated with Cl_2 gas to form chlorides, which are volatilized and selectively condensed.

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138. DUFFIELD, F. L. Recovery of Nickel and Other Metals From Ores Containing Nickel. British Patent 328,696, Feb. 8, 1929; British Chem. Abs., 1930, p. 669B.

The ore is roasted at 750°–1,000° C. until the iron is converted into oxide and the nickel and copper into sulfates. Sodium, magnesium, or calcium chloride is added, and the mixture is heated to 650° C. to convert the nickel and copper into chlorides, which are subsequently removed by raising the temperature enough to cause them to volatilize. The residual iron oxide is reduced with a gaseous reducing agent and separated from the gangue magnetically. The volatilized chlorides are dissolved in water and separated by chemical or electrolytic means.

139. KICHLINE, F. O. Nickel and Cobalt From Ferruginous Ores. U. S. Patent 1,590,525, June 29, 1926; Chem. Abs., vol. 20, 1926, p. 2974.

An alkali metal sulfate is added to the ore, and it is roasted at 675° C. to form a double nickel-alkali metal sulfate. Double sulfates of other metals, such as Fe, are decomposed and rendered insoluble.

140. REID, J. H. Separating Cobalt and Nickel. Canadian Patent 160,495, Feb. 9, 1915; Chem. Abs., vol. 9, 1915, p. 2055.

Cobalt and nickel are separated by melting the metals, introducing P vapor, and then separating the P compound.

PYRO TREATMENTS, OXIDIZED ORES AND OXIDES

REDUCTION, GENERAL

141. CARON, M. H. Treating Nickel Silicate Ores. U. S. Patent 1,346,175, July 13, 1920; Chem. Abs., vol. 14, 1920, p. 2612.

Nickel silicate ore is prepared for leaching out the Ni by subjecting it to a reducing roast and cooling it under nonoxidizing conditions.

142 MORRISON, WALTER LEONARD. Electric Furnace Treatment of Nickel Ore and the Development of a Commercial Process. Abs. of paper read before the Am. Elec. Chem. Soc., Met. Chem. Eng., vol. 9, No. 10, October 1911, p. 546; Eng. Index, 1911, p. 407.

Gives an account of the work done at Webster, N. C.

WITH GASEOUS REDUCTANT

143. CHEMICAL ENGINEERING. Reduction of Nickel Minerals. Vol. 20, 1948, pp. 338–340. Translated and condensed from Bogatskii, D. P. [Reduction of Silicate Minerals of Nickel With Carbon Monoxide.] Zhur. priklad. Khim., vol. 20, No. 1–2, 1947, pp. 81–88; Metals Rev., vol. 22, January 1949, p. 24.

The results of this experiment were obtained by reducing fine Russian ores with CO.

WITH SOLID REDUCTANT

144. CHALAS, ADOLPHE. Reducing Nickel Hydrosilicate Ores. U. S. Patent 959,460, May 31, 1910; Chem. Abs., vol. 4, 1910, p. 2261.

Nickel hydrosilicate ores are reduced by smelting a briquetted mixture of ore, hydraulic lime, and iron ore with fuel and limestone. After most of the pig iron is separated by gravity, the remaining molten slag is chilled with water, crushed, and magnetically treated to separate Ni-Fe granules therefrom.

145. STERN, M. Nickel. British Patent 269,133, Apr. 7, 1926; Chem. Abs., vol. 22, 1928, p. 1322.

Nickel-bearing material, such as oxides, scales, or ore, is melted with Fe which reduces the Ni and forms an iron and nickel alloy. The Fe may then be removed from this alloy to obtain Ni, by oxidation, or the alloy may be used repeatedly to treat further raw material.

ROASTING WITH A SALT OR SALT-FORMING GAS

146. ANNABLE, H. W. The Extraction of Nickel From Silicate Ores. Canadian Patent 183,827, Apr. 23, 1918; Chem. Abs., vol. 15, 1921, p. 3443.

The silicate nickel ore is heated in a furnace in the presence of moist H_2S to convert the $NiSiO_3$ to NiS. A small amount of NaCl may be added.

147. BABÉ, J., AND COLLIN, M. [Nickel From Oxide Ores.] French Patent 449,112, Dec. 13, 1911; Chem. Abs., vol. 7, 1913, p. 2537.

In producing nickel from oxide ores, a difficultly fusible ore is calcined with finely ground Sb or Sb_2O_3 at 1,000°–1,200° C., and an alloyed mass is formed which, after washing, contains 10 to 15 percent Sb–Ni, some Fe, S, etc. After fusion in the cupola furnace with KNO_3, BaO_2, etc., a product is obtained of about equal parts of Sb and Ni, which is separated by HCl into antimony and nickel salts; the latter, after Fe is removed by $CaCO_3$, is submitted to electrolysis.

148. DE ARANJO, H. E. [Metallurgy of Nickel in Brazil.] Rev. Soc. brasil. sci., vol. 2, 1931, pp. 438–441; British Chem. Abs., 1932, p. 681B.

It is proposed to fuse the ore with CaO and $CaSO_4.2H_2O$; nickel silicates are converted into sulfide. Excess of CaO is advised. The matte (Fe 30–40, Ni 30–40, S 25–28 percent) is blown in a Bessemer converter in presence of added SiO_2; iron silicate is formed, but NiS is unaffected. The latter is oxidized in a reverberatory furnace, the oxides are reduced, and Ni is purified electrolytically.

149. FOHLEN, J. L. Simultaneous Reduction of Nickel Ores and Conversion of Carbonaceous Materials Into Hydrocarbons of Low Boiling Point. British Patent 339,276, July 25, 1929; British Chem. Abs., 1931, p. 208B.

The gases from the destructive distillation of lignite are passed through a heated mass of garnierite and calcium sulfide, and the resulting nickel matte is separated from the slag, crushed, roasted to oxide, and reduced at 150° to 300° C. by the vapor of the liquid products from the lignite distillation; nickel powder and cracked hydrocarbon products of low boiling point are obtained. The combustible gases obtained in the process are used to heat the retorts and the rotary furnace in which the matte is produced.

SMELTING TO FERROALLOYS

150. BOGITCH, B. [The Smelting of Low-Grade Oxidized Ores in the Electric Furnace.] Jour. four élec., vol. 36, 1927, p. 246; Chem Abs., vol. 22, 1928, p. 30.

Bogitch investigated the electrosmelting of oxidized ores containing only 3 to 5 percent Ni+Co+Cu and appreciable quantities of iron oxides. The open-box-type arc furnace was tried but proved impractical. A single-phase, 1,000-kw., single-electrode arc furnace was finally chosen. The walls and roof were lined with chromite. A high-arc voltage—100 to 180 volts—is an essential feature. The current density is almost 10 a. per cm.^{2} of the cross section of the carbon electrode (15 cm. diameter). The power factor was 90. The carbon of the electrode does not act appreciably as a

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reducing agent. Coke is added as needed. The ferroalloy produced is virtually C and Si free. A ton of ore producing 70 to 100 kg. of ferroalloy required 1,000 to 1,250 kw.-hr. and 8 to 15 kg. of electrodes.

151. JOURNAL DU FOUR ÉLECTRIQUE ET DES INDUSTRIES ÉLECTROCHEMIQUES. [Electrometallurgical Treatment of Nickel Minerals in New Caledonia.] Vol. 24, 1919, p. 3; Chem. Abs., vol. 13, 1919, p. 537.

Hitherto it has been impossible to obtain ferronickel low in C and Si in the electric furnace. In 1912–13 garnierite was treated in an electric furnace for 8 months on a production scale. The charge was mineral, finely powdered wood charcoal, and lime to form a basic slag. Products were ferronickel with 50 and 75 percent Ni, less than ½ percent C, and about 0.2 percent Si; losses of Ni were less than 5 percent. A 2-electrode type furnace of 400 kw. capacity was used. Electric energy consumed per ton of 50-percent ferronickel was 1,300 kw.-hr., and electrode consumption was 125 kg. per ton.

152. PRICE, EDGAR F. (assigned to Central Trust Co. of New York). Reducing Nickel from Ores. U. S. Patents 909,666 and 909,667, Jan. 12, 1909; Chem. Abs., vol. 3, 1909, p. 1001.

A siliceous ore of Ni and Fe is smelted with C in an electric furnace, and the molten ferronickel is treated with air and an acid flux to remove Fe. The high-Ni product is treated with Si, Al, or ferrosilicon before casting.

PYRO TREATMENTS, NON-OXIDIZED ORES AND SALTS

REDUCTION TO METAL OR METALLURGICAL PRODUCT

153. BAGHDASARIAN, A. B., Extraction of Metals From Metallic Sulfides. Extraction of Metallic Nickel. U. S. Patents 1,671,003 and 1,761,004, May 22, 1928; appl. (*a*) Aug. 17, 1925, (*b*) July 19, 1926; British Chem. Abs., 1928, p. 609B.

(*a*) The sulfides are chloridized at a suitable temperature, and the chlorides are heated and reduced with hydrogen to give the metals. (*b*) A solution containing nickel is first treated to remove objectionable impurities, then most of the nickel is precipitated by adding metallic zinc. This zinc is collected, the clear solution is boiled, and more zinc is added to complete precipitation of the nickel.

154. BORCHERS, W., AND PEDERSEN, H. [Working Iron and Copper Containing Sulfidic Nickel Ores.] German Patent 248,802, Dec. 30, 1911, addition to German Patent 245,198 (*see* Chem. Abs., vol. 6, 1912, p. 2390); Chem. Abs., vol. 6, 1912, p. 2909.

Discusses working iron- and copper-containing sulfidic nickel ores or foundry products, by a combination of melting, roasting, extraction, and precipitation. Gives detailed examples.

155. ———. Extraction of Copper and Nickel from Low-Grade Ores. Canadian Patent 207,908, Jan. 25, 1921; Chem. Abs., vol. 15, 1921, p. 6643.

Copper and nickel matte is roasted and leached with acidulated water. Copper is precipitated with H_2S and the precipitate reduced to metallic copper; the residual $NiSO_4$ solution is evaporated and the $NiSO_4$ roasted to form NiO, which is then reduced to metallic form.

156. BURROWS, L. P. Refining Nickel. Canadian Patent 165,916, Nov. 9, 1915; Chem. Abs., vol. 10, 1916, p. 1164.

Nickel is desulfurized, reduced, and refined by applying the gas or gases derived from water that are produced by suddenly expanding steam, separating the steam without condensation from any water suspension, heating the gaseous product to a high temperature, and subjecting the Ni ore to the action of the resultant gaseous product in a chamber from which atmospheric oxygen is excluded.

157. CITO, CAMILLO C. Smelting Silver-Nickel-Cobalt-Arsenic Ores. U. S. Patent 949,059, Feb. 15, 1910; Chem. Abs., vol. 4, 1910, p. 1014.

Smelting silver-nickel-cobalt-arsenic ores with a percentage of Cu, at least equal to that of the As and not less than that of the Ag, forms an alloy of Cu, Ag, Ni, Co, and virtually all the As and a slag containing a very low percentage of Ag, Ni, and Co.

158. ———. Smelting Silver-Nickel-Cobalt-Arsenic Ores. U. S. Patent 949,261, Feb. 15, 1910; Chem. Abs., vol. 4, 1910, p. 1014.

Smelting silver-nickel-cobalt-arsenic ores with a percentage of Cu, at least equal to that of the As and not less than two-thirds that of the Ni and Co, forms an alloy of Cu, Ag, Ni, Co, and virtually all the As.

159. ———. Treating Silver-Nickel-Cobalt-Arsenic Ores Free From Lead. U. S. Patent 949,058, Feb. 15, 1910; Chem. Abs., vol. 4, 1910, p. 1014.

The ore is smelted with Cu to produce an alloy containing the Cu; all the Ag, Ni, and Co; and most of the As. Then the metals are separated by electrolysis from an anode of the alloy in an electrolyte of $CuSO_4$ solution containing a small amount of free H_2SO_4.

160. WESTDEUTSCHE THOMAS-PHOSPHAT WERKE. [Working Ores by a Two-Phase Process.] German Patent 294,119, May 20, 1914; Chem. Abs., vol. 12, 1918, p. 123.

Sulfide ores containing Ni, Fe, and S are concentrated to form a Ni-Fe or NiO product rich in Ni. Previously roasted ores were electrolytically smelted, yielding iron, nickel, and their sulfides. This product is bessemerized until the Ni begins to oxidize to NiO. The resulting product is principally Ni, some dissolved NiO, and a little unoxidized Fe. This Ni product is reduced to combined Ni and pure Ni by dry or wet smelting, as well as electrolytic treatment.

161. WRIGHT, SYDNEY B. The Smelting and Refining of Cobalt Silver Ore. Eng. Min. Jour., vol. 107, No. 6, Feb. 8, 1919, pp. 263–264; Eng. Index, 1919, p. 430.

The Deloro Reduction Co. treats both high- and low-grade silver cobalt ore in lump form, including jig and table concentrates, and ore residues.

REDUCTION TO MATTE OR SPEISS

162. BELTZER, FRANCIS J. G. The Rational and Industrial Treatment of the Complex Ores of Silver, Cobalt, Nickel, and Arsenic of Cobalt, Ontario. Mon. Sci., vol. 13, pp. 633–647; Chem. Abs., vol. 4, 1910, p. 1010.

The ores average 5,000 to 8,000 oz. Ag, 7 to 15 percent Co, 2 to 8 percent Ni, and 35 to 45 percent As. The process recommended is to concentrate as much as possible; separate the native Ag by amalgamation; then roast off the As as As_2O_3, refining the fume for the market, or roast the As with CaO, soda, or bisulfate, dissolving out the arsenite with water. If the As is roasted off as As_2O_3, roast it again with NaCl and extract Ag by amalgamation, adding Zn or Fe chips to the mechanical amalgamator. If the As is roasted with CaO, soda, or bisulfate, remove the Co and Ni as soluble sulfates. From the sulfates or chlorides of these metals, precipitate the Co as oxide with lime and Cl_2 or with NaClO. Half the solution is used, then the remaining half is added; the precipitation is completed by the

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reaction $Co_2O_3+Ni_2O_3+2CoCl_2=2NiCl_2+2Co_2O_3$. The nickel is finally precipitated by soda as oxide. An alternate process is to mix the ore with a lead furnace charge, collecting the Ag in the lead and the Co, Ni, and As as a speiss. The speiss is roasted with carbon to remove As, the Co combines with SiO_2 added as silicate, and the Ni is still combined with the unremoved As. Solution in HCl and precipitation with limewater recovers the Ni and Co as hydroxides.

163. BOGITCH, B. Sur le grillade des sulfures; des mattes de nickel en particulier. [An Account of Sulfide Roasting; of Nickel Mattes in Particular.] Acad. Sci., vol. 196, No. 11, Mar. 13, 1933, pp. 782–784; Eng. Index, 1933, p. 793.

Nickel sulfide mattes are roasted at a low temperature to remove most of the sulfur. Regrinding the sinter and reroasting at 1,200° to 1,300° C. eliminates the remaining S.

164. BORCHERS, WILHELM, AND WARLIMONT, FELIX. [Working Iron- and Copper-Containing Sulfide Nickel Ores.] German Patent 200,467, May 18, 1907; Chem. Abs., vol. 2, 1908, p. 3055.

A process for working iron and copper containing sulfide nickel ores or furnace products by roasting, lixiviating, and melting is described. Sulfate roasting is done at such a low temperature that most of the Cu, with the Co present, is converted into the water-soluble sulfate and most of the Fe into insoluble oxide, with which most of the Ni remains as insoluble sulfide. This residue is treated to yield a copper-free Ni ore, the resulting matte being electrolyzed or roasted and reduced. Platinum, if present, deposits on the anode.

165. HARTOGENSIS, VIKTOR V. [Treatment of Sulfur-Nickel Ores Containing Iron and Copper.] French Patent 437,774, Apr. 30, 1912; Chem. Abs., vol. 7, 1913, p. 1475.

A rock that is poor in Cu and Ni but rich in Fe and S is melted in the electric furnace, with or without a flux (such as lime), and the resulting matte is roasted at about 600° C. to convert the 2 metals into their sulfates. After extraction, the residue is added to the original mass of ore, and the lye is precipitated out with alkali and alkaline earth sulfates. The two sulfates are separated and reduced with lime or coal, and the CaS slag is utilized to produce Na_2S with Na_2SO_4. The slags from the fusion are used for building materials.

166. HARRIS, CARR A. Experiments in Cobalt-Silver-Nickel Smelting. Eng. Min. Jour. Press, vol. 118, 1924, pp. 214–216; Chem. Abs., vol. 18, 1924, p. 3162.

A good speiss is obtained by reducing the coke to 2.5 to 3.5 percent of the charge, keeping the Fe at 17 to 18 percent and increasing the sandstone, which should be high in free SiO_2. Experiments establish that: (1) A good grade of speiss is made in the blast furnace in one operation, with enough slag, speiss, and sandstone to carry the fine material along and assist in melting the charge; (2) sintered ores may be smelted at the rate of 40 to 60 tons per 24 hours, with small coke consumption and a high-grade speiss. The quantities of Ag and As in the furnace and in the speiss depend more or less upon the other metals present and are even predicted from the iron content. Cobalt-nickel and iron speisses can easily be blown in a converter; the Co and Ni are not oxidized with the iron. The course of the Ag is indicated.

167. MABEE, H. C., AND SMAILL, A. E. Combined Pyro- and Hydro-Metallurgical Process for the Treatment of Nickeliferous Pyrrhotite Ores With the Subsequent Recovery of Iron, Sulfur, Nickel, and Copper. Canadian Dept. Mines, Mines Branch Rept. 643, 1926, pp. 105–108; British Chem. Abs., 1926, p. 671B.

The present processes for recovering nickel and copper from Sudbury pyrrhotites wastes all the iron and sulfur content. If the ore is smelted in a reverberatory or electric furnace with limestone to flux all the gangue, a low-grade nickel-copper matte is obtained, which contains virtually all the nickel, copper, iron, and sulfur originally present. If the matte is roasted at 450° to 500° C., 85 percent of the sulfur is recovered as sulfur dioxide. Then the roasted material is mixed with 10 percent of sodium chloride and 5 to 10 percent of water and introduced into a rotating furnace held at 450° to 500° C. in such a way that the charge is heated gradually as it passes through the furnace. Leaching the product results in solution of 98 percent of the copper and 75 percent of the nickel, leaving an iron oxide containing 3 to 4 percent Ni and about 0.4 percent S, which could be used for the direct production of nickel steel.

168. MASON, F. H. The Metallurgy of Nickel. Rept. Royal Ontario Nickel Comm., Min. Sci. Press, vol. 116, 1918, pp. 233–236; Chem. Abs., vol. 12, 1918, p. 893.

Discusses bessemerizing Ni–Cu matte, and gives a detailed description of Sudbury practice. The coarse ore is roasted in heaps and the fine ore in Wedge roasters; the former is smelted in blast furnaces and the latter in reverberatories. The Mond Nickel Co. sinters the fine ore in two Dwight-Lloyd mechanical roasters and smelts it in a blast furnace instead of a reverberatory. This company produces a converter matte having an average analysis of Ni 41, Cu 41, S 17, and Fe 0.6 percent. Canadian Copper Co. converter matte contains 50–55 percent Ni, 25–30 percent Cu, 20–21 percent S, and 0.2–0.5 percent Fe. New Caledonian ores contain neither Cu nor S and average 7 to 8 percent Ni. They are smelted in small blast furnaces that have a daily capacity of 25 to 30 tons of ore; the charge comprises ore, limestone, gypsum, and coal or coke ground together, briquetted, and smelted with coke. The resulting matte contains 50–55 percent Ni, 25–30 percent Fe, and 16–18 percent S. The matte is refined by the Orford, Mond, and Hybinette processes, which are described.

169. NORDIN, W. Petsamo Nickel. Metal Ind., vol. 73, Sept. 3, 1948, pp. 183–185 (trans. and condensed from Vuoriteollisuus); Metals Rev., vol. 21, November 1948, p. 6.

Describes processes and equipment used for concentration and smelting. The ore is charged directly to an arc furnace; upon fusion, the sulfides settle and the gangue is skimmed off.

170. PEDERSEN-TRONDHJEM, HAROLD. [Studies Regarding the Simplification of the Smelting of Sulfide Nickel Ores and Smelter Products Carrying Iron and Copper.] Metall. u. Erz, vol. 10, 1912–13, pp. 384–403; Chem. Abs., vol. 7, 1913, p. 2033.

The principles of the standard processes are described, and the following process is proposed for places where hydroelectric power is cheap and coal is high: (1) Electrolytic smelting of the ore for matte; (2) sulfatizing roast; (3) leaching with water to remove the Ni and Cu (the residue containing a small amount of Ni and Cu is used as an iron flux in the smelting); (4) adding NiO and blowing air through the solution to precipitate Fe; (5) precipitating Cu with H_2S; (6) evaporating the solution and recovering Ni as NiO; (7) reducing NiO to Ni by heating with C; and (8) working up the Cu_2S by standard methods.

171. PHILLIPS, W. Smelting Cobalt-Silver Ores. U. S. Patent 1,127,506, Feb. 9, 1915; Chem. Abs., vol. 9, 1915, p. 781.

Smelting raw cobalt-silver ores with raw iron matte and Cu residue forms speiss, argentiferous Cu matte,

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and slag. Smelting the speiss repeatedly with fresh raw Fe matte removes the Ag and Cu. Nickel and cobalt are recovered from the residual speiss.

172. SJOSTEDT, E. A. Development in the Nickel Industry at Sault Ste. Marie, Ontario, Canada. Eng. Min. Jour., vol. 75, No. 17, Apr. 25, 1903, p. 632; Eng. Index, 1901–05, p. 814.

Monosulfides are roasted without auxiliary heat at Sault Ste. Marie.

173. SMITH, S. C. Treatment of Nickeliferous Material (South African Copper-Nickel-Platinum Concentrates). British Patent 311,909, Apr. 18, 1928; British Chem. Abs., 1929, p. 562B.

The ore is smelted to matte, which is roasted and reduced to a metal sponge by coal gas or other reducing agent. The metal sponge is leached with hot, dilute sulfuric acid; then air is drawn through the mass, causing oxidation and a rise in temperature. A second charge of acid is passed through the mass, and oxidation with air is repeated. Alternate leaching and oxidation are continued until no further metal is extracted; the residue is again roasted and reduced; and leaching and oxidation are repeated until a product is obtained with a high content of platinum metals that can be refined by known methods.

174. VON ZEERLEDER, A. [Smelting of Copper-Nickel Sulfide Ores in the Electric Furnace.] Metall. u. Erz, vol. 13, 1916, pp. 453–462, 473–481, 494–505; Jour. Soc. Chem. Ind., vol. 36, p. 883; Chem. Abs., vol. 12, 1918, p. 118.

Smelting experiments in an electric shaft furnace with an ore from the Black Forest that had hitherto been neglected gave promising results. Experiments in a Girod furnace of 300 kg. capacity yielded a matte with 4.9 percent Ni, 4.1 percent Cu, 30.5 percent S, and 60 percent Fe and a ferronickel with 13.8 percent Ni, 0.72 percent Cu, 8.37 percent Si, 1.32 percent S, and 75 percent Fe. About 91 percent of the Ni and 77.5 percent of the Cu were recovered.

PYRO TREATMENTS OF MATTE OR SPEISS

175. CANADIAN INSTITUTE OF MINING AND METALLURGY. The Mining and Smelting Operations of the International Nickel Co. of Canada, Ltd. Monthly Bull. 100, August 1920, pp. 614–654; Eng. Index, 1920, p. 401.

Presents a detailed account of roasting and smelting operations in blast or reverberatory furnaces and of converting matte in basic converters.

176. CARRICK, JAMES T. Treatment of Copper or Copper-Nickel Mattes. U. S. Patent 939,947, Nov. 9, 1909; Chem. Abs., vol. 4, 1910, p. 437.

The matte is digested in acid, the residual cuprous sulfide is bessemerized, and the Ni is slagged off as silicate; the H_2S produced in the first step is used as fuel in the bessemerizing process.

177. EDWARDS, H. W. Bessemerizing Nickel Matte. Eng. Min. Jour., May 2, 1896, p. 422; Eng. Index, 1896–1900, p. 669.

Gives account of work from 1891 to 1894, when the author operated a nickel-smelting plant in the Sudbury district comprising two blast furnaces and a set of Bessemer converters.

178. GIERTSEN, S. Bessemerizing Copper-Nickel Matte. U. S. Patent 1,538,431, May 19, 1925; Chem. Abs., vol. 19, 1925, p. 2025.

After virtually all the iron has been removed, blowing is continued and ferrosilicon or other heat-producing material is added to produce anode material.

179. GRÖNWALL, E. A. A. Recovery of Cobalt or Its Compounds From Mattes. British Patent 357,366, Sept. 16, 1930; Swedish Patent, Sept. 17, 1929; British Chem. Abs., 1931, p. 1103B.

Copper matte obtained by the usual method from cobaltiferous Cu pyrites is bessemerized until all or most of the Fe has been slagged and removed. Blowing is continued, and SiO_2 is added to slag off the Co; the resulting cobalt silicate is crushed and leached with H_2SO_4 to extract Co. It is then smelted with more Cu pyrites to yield a cobalt-rich matte, or roasted with pyrites and NaCl to yield soluble Co salts. Reducing the slag in an electric furnace affords a crude metal from which pure Co may be recovered by wet methods.

180. INTERNATIONAL NICKEL CO. Extracting Copper and Nickel. British Patent 138,600, Jan. 12, 1920; Chem. Abs., vol. 14, 1920, p. 1805.

Copper and nickel matte is smelted in a cupola furnace with an alkali sulfide, and the molten sulfides are allowed to solidify in a large pot. The upper layer contains impure double sulfides of Na and Cu and Na and Fe, and the lower layer of impure NiS contains some Cu, Fe, and precious metals. The upper layer is taken to a converter and blown to blister copper. The lower layer is crushed and leached to remove soda and iron, roasted to oxide, and reduced in a furnace to impure metal, which is cast into ingots and refined electrolytically; pure Ni sheets are used as cathodes, the impure ingots as anodes, and nickel sulfate as electrolyte.

181. ———. Treating Nickel Mattes. British Patent 271,282, July 16, 1926; Chem. Abs., vol. 22, 1928, p. 1568.

In direct conversion of nickel-containing mattes into Ni with the elimination of S, additional heat is supplied from above the level of the bath to supplement that developed from the converting action, and the oxygen content of the bath is lowered during the last stages of conversion to prevent preferential oxidation of metal in the bath. Slag-forming materials may be added, and the converter may be lined with fused Al_2O_3 bonded with china clay. Structural details of the converter are described.

182. KERN, E. F., AND MERRIS, M. H. Roasting of Copper-Nickel Matte. Columbia Univ. Sch. Mines Quart., vol. 35, pp. 1–21; Chem. Abs., vol. 8, 1914, p. 1080.

Heating a mixture of NiS and CuO to 525° to 600° C. produces small quantities of $CuSO_4$ and $NiSO_4$. Above 650° C. no sulfates are formed, but mutual interaction produces Cu_2S plus mixed subsulfides. Nickel subsulfide is very stable. When a mixture of nickel subsulfide and CuO is heated, no reaction is apparent. Roasting Cu-Ni matte proceeds slowly below 600° C.; above 730° C. the matte particles become pasty and cake into masses that prevent rapid oxidation. The most rapid and complete roasting of Cu-Ni matte is obtained by first roasting it for 1 hour at 450° to 500° C. with free access of air, then raising the temperature to 675° to 725° C. Vigorous rabbling while roasting is necessary to prevent fritting of matte particles. In analysis of Cu-Ni materials, Cu may be separated from Ni by boiling a solution of sulfates with a strip of Al in the presence of 3 cc. of concentrated H_2SO_4 per 100 cc. of solution. The report includes thermal diagrams of Cu-Ni sulfides and Cu-Ni alloys and photomicrographs of Cu-Ni mattes.

183. KERN, EDWARD F., AND WALTER, H. W. Roasting of Nickel-Copper Matte. Columbia Univ. Sch. Mines Quart., Aug. 1911; Eng. Index, 1911, p. 368.

Experimental investigations are reported.

184. LANGER, C. Treating Nickel-Copper Matte. British Patent 109,401, Mar. 17, 1917; Chem. Abs., vol. 12, 1918, p. 37.

Nickel and copper matte is calcined, and the resulting mixture of oxides is treated with acid, preferably

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dilute H_2SO_4, giving a solution of $CuSO_4$. The residue is dried and reduced to metal, mainly Ni, which is used to precipitate the Cu from the $CuSO_4$ solution, producing $NiSO_4$ solution; precipitation is done in vessels provided with agitators. The $NiSO_4$ may be obtained by crystallization, or the solution may be electrolyzed using insoluble anodes. The precipitated Cu may be refined electrolytically or may be converted into oxide by calcination, then into sulfate.

185. LELLEP, O. Treating Matte Containing Nickel or Nickel and Copper. U. S. Patent 1,278,176, Sept. 10, 1918; Chem. Abs., vol. 12, 1918, p. 2311.

Matte to be treated is introduced while still liquid from previous operations into a furnace or converter heated from an outside source to 1,000° to 1,200° C. The temperature of the mass is raised to about 1,750° C., at which temperature reaction velocity for S elimination is greater than for formation of nickel oxide; then the material is oxidized by a blast of air or other oxidizing agent. The mass is preferably slightly overoxidized, and resulting oxides are reduced by the action of C, CO, Mg, or other reducing agents. To insure production of pure metallic nickel from nickel matte or Ni-Cu alloy from Ni-Cu matte, the last traces of S may be removed by treating the material at a high temperature with a basic slag containing CaC_2.

186. MAFFETT, ROBERT R., Separating Nickel From Copper. U. S. Patent 838,125, Dec. 11, 1906; Chem. Abs., vol. 1, 1907, p. 652.

The matte is fused with an alkaline sulfate and carbon, together with sulfur. The sulfate is reduced to a sulfide and the polysulfide acts on the matte.

187. MCKENNA, P. M., Separating Cobalt From Speiss. U. S. Patent 1,166,067, Dec. 28, 1915; Chem. Abs., vol. 10, 1916, p. 587.

Speiss containing Co and Ni is fused with B_2O_3 about equal in weight to the Co in the speiss, and gravity separation is effected between the speiss and the boric cobalt slag formed. The latter is then heated to about 1,000° C. in an oxidizing atmosphere to expel As and Sb. The Fe may be removed, if desired, by melting with SiO_2 as a preliminary operation.

188. METAL INDUSTRY (LONDON). Present-Day Nickel Converter Practice. Vol. 40, No. 1, July 1, 1932, pp. 3–4, 18; Eng. Index, 1932, p. 883.

Working details of nickel converter practice in England are discussed, with special emphasis on separating iron from nickel matte, also temperature conditions, slagging operations, refractories and linings, and oxidation of nickel.

189. MOHR B., AND HEBERLEIN, C. Extracting Copper and Nickel. British Patent 125,642 Sept. 29, 1916; Chem. Abs., vol. 13, 1919, p. 2162.

Copper and nickel in bessemerized Cu-Ni matte are separated by calcining the finely ground matte until the sulfides become oxides, reducing the calcined matte, treating the reduced matte with acid to dissolve the Ni but not the Cu, then electrolyzing the Ni solution to deposit Ni. The anodes and cathodes of the electric cell may be Pb and Ni, respectively. The electrolyte, containing about 10 percent of free H_2SO_4, flows into the first of a series of leaching vats, into which reduced matte is fed to produce a fresh supply of electrolyte.

190. NORDDEUTS, AFFINERIE. [Recovery of Nickel and Cobalt or Pure Salts Thereof From Speiss.] British Patent 369,120, July 22, 1931; German Patent, Sept. 9, 1930; British Chem. Abs., 1932, p. 472B.

Speiss containing Cu, Pb, Fe, Ni, and Co and small quantities of precious metals is mixed with S and fused in a reverberatory furnace to obtain a Cu–Pb–Fe matte of the precious metals and a concentrated Co–Ni speiss. The latter is finely ground and heated at 200° C. with H_2SO_4 in a cast-iron pan to produce As_2O_3, Sb_2O_3, and sulfates of the other metals. Excess H_2SO_4 is removed by suction, and the paste is washed with a little cold water then boiled with water to separate the soluble sulfates from the insoluble acid oxides. The solution is treated to recover $NiSO_4$ and $CoSO_4$, and the residue is roasted to remove As_2O_3 then smelted to recover Sb, Pb, and precious metals.

191. PEEK, R. L., AND KNITTEL, C. A. (assigned to International Nickel Co., Inc.) Treatment of Nickel-Bearing Materials, Matte. British Patent 379,322, Apr. 24, 1931; U. S. Patent, Aug. 15, 1930; British Chem. Abs., 1932, p. 989B.

Nickel matte with 74–76 percent Ni, 1.5–2.5 percent Cu, and 0.2–0.5 percent Fe is desulfurized in a downdraft sintering apparatus until it contains less than 0.6 percent S. About 5 percent of the roasted product is finely ground and reduced to metal sponge with water gas at less than 500° C., and the remainder is smelted with coke and cast into crude Ni anodes. The anodes are refined by electrolysis in a $NiSO_4$ solution, which is purified from time to time by treatment with the sponge; this process precipitates the Cu and reduces the pH to 5.6, at which point the Fe is precipitated by blowing air through the solution. The solution is then returned to the tanks.

192. RICHARDSON, C. G. Separating Cobalt From Nickel. U. S. Patent 1,557,879, Oct. 20, 1926; Chem. Abs., vol. 20, 1926, p. 167.

Purified speisses containing Ni, Co, As, and Sb are roasted to the point at which an amount of As equivalent to that necessary for combination with the Co has been eliminated. The material may then be smelted with fluxes to produce a slag containing the Co and a new speiss containing the Ni, As, and Sb.

193. STANLEY, R. C. Separating Nickel and Copper From Mattes. Canadian Patent 199,647, Apr. 27, 1920; Chem. Abs., vol. 14, 1920, p. 1960.

Copper and nickel matte is smelted with an alkali sulfide (niter cake) in a cupola furnace. Material high in Cu (tops, reverts, etc.) is added, and the molten sulfides are charged into a reverberatory furnace to settle the Ni; some Cu and the precious metals go to the bottom. The layers are tapped off separately; the Cu is blown in a converter to blister Cu, and the Ni is allowed to solidify to separate out sodium and iron sulfides. The Ni bottoms are again smelted with niter cake. The product is then crushed and leached to remove Na and Fe; the purified sulfide is converted into the oxide, which is then reduced to metallic Ni, melted, and cast into ingots to be used as anodes.

194. ———. Nickel and Copper From Mattes, Etc. U. S. Patent 1,553,197, Sept. 8, 1925; Chem. Abs., vol. 19, 1925, p. 3473.

In treating mattes or similar material, the Cu material is partly separated from the Ni by furnace treatment, and the Ni material still containing some Cu is blown directly to produce metallic Ni containing a small proportion of Cu.

195. ——— (assigned to International Nickel Co.). Separating Nickel and Copper From Copper-Nickel Mattes or Other Material. English Patent 240,789, May 28, 1925, conv. Sept. 30, 1924 (*see* U. S. Patent 1,553,197, Sept. 8, 1925); British Chem. Abs. 1925, p. 888; British Chem. Abs., 1926, p. 92B.

196. ——— (assigned to International Nickel Co.). Treatment of Nickel-Copper-Bearing Material. British Patent 351,150, Apr. 23, 1930, appl., Aug. 17, 1929; British Chem. Abs., 1931, p. 812B.

Bessemerized Cu-Ni matte is smelted with Na_2SO_4

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and C, the top layer of Cu-Na sulfides is removed, and the bottom layer is smelted again with Na_2SO_4 and C. The combined top layers are treated in a converter to obtain blister Cu; and the final bottom layer is ground, leached to remove soda and Fe, and roasted to NiO, which is treated by the carbonyl process to recover pure Ni.

197. TAFEL, V., AND KLEWETA, F. Über die Vorgänge beim Verblasen von kupferhaltigem Nickelstein. [Phenomena Occurring With Blowing of Copper Bearing-Nickel Matte.] Metall. u. Erz, vol. 27, No. 4, Feb. 2, 1930, pp. 85–88, 1 fig.; Eng. Index, 1930, p. 1201.

Analyzes the influence of copper content on separating metallic nickel in blowing nickel matte.

198. WADE H. (assigned to International Nickel Co.). Bessemerizing of Nickel-Containing Mattes. British Patent 349,700, Mar. 28, 1930; British Chem. Abs., 1931, p. 765B.

Nickel or Ni–Cu matte containing 18 to 20 percent of S is blown in a converter at 1,330°–1,500° C. with a 9 : 1 mixture of steam and air preheated at 500° C. until the S is reduced to 2 to 4 percent. The temperature is then raised to about 1,600° C., and the material is blown with superheated steam without air until the resulting metal contains 0.005 to 0.02 percent S. The charge is then deoxidized with C, Si, Mg, Al, or Ca. The two-stage blowing operation is preferable to the single-stage process, as it prevents excessive corrosion of the refractory lining.

ROASTING WITH A SALT OR SALT-FORMING GAS

199. ANNABLE, H. W. C. The Recovery of Nickel From Its Sulfides. Canadian Patent 224,406, Oct. 3, 1922; Chem. Abs., vol. 16, 1922, p. 4180.

Nickel-containing material and a metallic sulfide are heated with a metallic chloride from 800° to 1,000° C. in a neutral atmosphere to convert the Ni into sulfide. The mixture is roasted to produce $NiSO_4$ and to decompose the sulfates of Fe and Cu. The soluble $NiSO_4$ is then leached.

200. BOGITCH, G., [Treatment of Nickel Ores.] Compt. rend., vol. 194, 1932, pp. 1500–1502; British Chem. Abs., 1932, p. 644B.

An ore, which after calcination contained Ni 10.3, Fe 7.02, MgO 5.6, Al_2O_3 22.4, SiO_2 42.5 percent, was smelted with various proportions of coke with CaO and $CaSO_4$. With 100 parts of ore and 20 parts of CaO, increasing the coke (2 to 6 parts) increased Fe in the metal and decreased Ni in the slag (22.3 percent Fe and 0.40 percent Ni for 5 parts of coke). With 5 parts of coke, increasing the CaO (0 to 30 parts) diminished Ni in the slag but increased Fe in the metal (0.40 percent Ni and 22.3 percent Fe for 20 parts of CaO). Increasing the proportion of Fe by adding ore containing 12 percent Fe increased Fe in the metal and Ni in the slag. Replacing part of the CaO with $CaSO_4$ introduced S into the matte, although not in proportion to the amount of $CaSO_4$, and decreased the Fe but increased the Ni in the slag. The maximum advantageous proportion of $CaSO_4$ is double that of Ni in the ore.

201. BURROWS, L. P. Nickel. French Patent 479,606, Apr. 19, 1916; Chem. Abs., vol. 11, 1917, p. 776; British Patent 12,358, Aug. 27, 1915; Chem. Abs. vol. 11, 1917, p. 246.

Nickel is desulfurized, reduced, and refined in a chamber, from which atmospheric oxygen is excluded, by steam that has been suddenly expanded; then it is separated from water held in suspension and heated to high temperature. Compounds that will give off Cl_2 or N_2 may be mixed with the ore. A suitable construction is specified.

202. ———. Treating Nickel Ore. U. S. Patent 1,424,710, Aug. 1, 1922; Chem. Abs., vol. 16, 1922, p. 3301.

Crushed Ni ore is subjected to a suitable gas or vapor in a closed chamber until the O_2 is removed from the ore, then it is smelted. The metallic product is broken up and disintegrated by exposing it to the atmosphere, then it is heated to low redness until its weight is reduced about 20 percent to yield a material for manufacturing alloys.

203. CARPENTER, A. H. Chloridizing Sudbury Copper-Nickel Ores. Eng. Min. Jour., vol. 97, pp. 1085–1089; Chem. Abs., vol. 8, 1914, p. 2545.

Experiments show that the Longmaid-Henderson process may be applied to these ores.

204. DUDLEY, B., JR., The Chloridizing Roast and Its Application to the Separation of Copper From Nickel. Bull Am. Inst. Min. Eng., vol. 1914, pp. 2767–2782; Chem. Abs., vol. 9, 1915, p. 429.

The completeness of chloridation of Cu increases with increasing temperature and time. Nickel does not become water soluble or volatilize to any extent when the temperature of the roast is above 650° C., whereas temperatures above 650° C. are favorable to chlorination of Cu. The increasing tendency of Ni to volatilize in the presence of Cu is because of the mechanical influence exerted on $NiCl_2$ by the volatilization of $CuCl_2$. Dudley's experiments indicate that roasted pyritic ores containing Ni and Cu may be treated commercially by chloridizing the Cu and leaching it from Fe and Ni oxides, leaving a product to be smelted to nickel-bearing pig iron.

205. JOHNSON, W. McA. Treating Ores Containing Copper, Nickel, Iron, and Precious Metals. U. S. Patent 1,238,298, Aug. 28, 1917; Chem. Abs., vol. 11, 1917, p. 3016.

Ore or matte that may contain Cu, Ni, Fe, and precious metals is subjected in closed chambers, after crushing, to the action of Cl_2 to remove the S from the ore by volatilization. The metal chlorides are then dissolved from the ore with water, Cu and precious metals are recovered from the solution, and Fe and Co are precipitated as hydroxides. These hydroxides are redissolved, and only the Fe is precipitated from the solution by adding Cl_2 and NaOH or $Ca(OCl)_2$ and Na_2CO_3. The solution, which still contains Ni, is evaporated and $NiCl_2$ crystallized from it. The $NiCl_2$ may be reduced in a retort, with H_2 or water gas and powdered coal, at a red heat.

206. KICHLINE, F. O. (assigned to Bethlehem Steel Co.). Extracting Nickel and Cobalt From Ferruginous Ores. U. S. Patent 1,590,525, June 29, 1926, appl. Oct. 10, 1922; British Chem. Abs., 1926, p. 755B.

A complex iron ore containing nickel or cobalt is mixed with an alkali sulfate and roasted at 680° C. Nickel sulfate may be separated by lixiviation from the product; most of the sulfates of other metals are decomposed and rendered insoluble.

207. MABEE, H. C., AND SMAILL, A. E. Combined Pyro- and Hydrometallurgical Process for the Treatment of Nickeliferous Pyrrhotite Ores With the Subsequent Recovery of Iron and Sulfur in Addition to Nickel and Copper. Canadian Dept. Mines, Mines Branch Rept. 643, 1924, pp. 104–108; Chem. Abs., vol. 20, 1926, p. 2305.

In preliminary smelting a reverberatory or electric furnace is recommended to avoid oxidation. For a successful chloridizing roast, moisture and O_2 must be present to oxidize the S still present in the charge, thus furnishing the necessary acid radicals to liberate Cl_2 from the chloridizing agent. By careful

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control 98 percent of the Cu and 75 percent of the Ni were recovered, with a residue containing nearly 100 percent of the iron as a finely divided oxide. The oxide still contained enough Ni to produce a steel that doubtless would be superior to that obtained by adding Ni directly to the molten steel bath.

208. ———. A Combined Pyro- and Hydrometallurgical Process for the Treatment of Nickeliferrous Pyrrhotite and Other Sulfide Ores for the Recovery of Iron and Sulfur in Addition to the Other Contained Metals. Canadian Dept. Mines, Mines Branch Rept. 670, 1926, pp. 89–94 (*see* Chem. Abs., vol. 20, 1926, p. 2305); Chem. Abs., vol. 21, 1927, p. 724.

With a specially designed chloridizing furnace, 92 percent of the copper and 41 percent of the nickel values of the ores were recovered in a solution from which the metals were easily extracted by electrolysis. The residues, as finely divided oxide, represent a recovery of 96 percent of the iron and the remainder of the nickel.

209. MAEF, E. E. Copper: Nickel; Sodium Salts. British Patents 168,097, Apr. 20, 1920, and 169,247, June 19, 1920; Chem. Abs., vol. 16, 1922, pp. 319, 707.

Finely divided copper and nickel matte, or a mixture of copper and nickel sulfides, is heated with powdered NaOH or with a mixture of NaOH and Na_2CO_3, NaCl, Na_2SO_4, Na_2S, or CaO, with or without a small proportion of powdered coal. The operation may be performed in an open or closed vessel, in a rarefied or inert atmosphere, or in H_2. Sulfides, hydrosulfides, and thiosulfates of Na are formed, and metallic Cu and Ni are precipitated. Calcium oxide, with or without other salts, may be used instead of NaOH, but a higher temperature is required. The molten salts may be poured off, or the whole mass may be treated with water to dissolve the salts. The mixture of metals may be separated by a carbonyl process or treated with H_2SO_4 to form NiS, the undissolved Cu being refined electrolytically or converted into oxide and thence into sulfate.

210. MANZ, H. [Roasting of Copper-Nickel Ores.] Chem.-Ztg., vol. 39, 1915, pp. 693–694; Chem. Abs., vol. 9, 1915, p. 3049.

Sulfide ores containing 6.6 percent Cu, 11.1 percent Ni, and 32.4 percent Fe, roasted direct in lots of 0.5–5.0 kg., gave 20–40 percent of the Cu and 22–26 percent of the Ni soluble in water. When mixed with Fe_2O_3, SiO_2, or roasted residues, the percentage extraction of Cu was nearly doubled; that of Ni was scarcely changed. Allowing the moist roast to stand 3 days only slightly increased the water-soluble part. By roasting at the lowest possible temperature (under 600° C.) with 20 percent NaCl and stopping at the right time, about 90 percent of the Cu and Ni was soluble in water and only about 10 percent of the Fe. The time averaged about 24 hours. Results are tabulated.

211. SMAILL, A. E. Treating Ores. U. S. Patent 1,593,509, July 20, 1926; Chem. Abs., vol. 20, 1926, p. 3152.

Ores containing sulfur and metal values, such as Fe, Ni, and Cu, are melted with Na_2CO_3 or other alkali flux under nonoxidizing conditions. The slag formed is removed, and the sulfur and metal values are recovered in a self-disintegrating matte without substantial loss.

212. VINGNER, J. B. M. E., AND PIERRON, P. R. Nickel and Nickel Alloys. Swedish Patent 40,729, May 31, 1916; Chem. Abs., vol. 10. 1916, p. 2347.

Nickel and nickel alloys are produced from C and S compounds or crude ore, in an electric furnace without a C hearth, by allowing one or more oxides or carbonates of the alkaline earths or similar materials to act on the fused compounds. The alkaline-earth metals are reduced by the C and convert all the S, forming simple or complex sulfides, whereas the C is converted into oxide and cannot unite with the Ni.

213. WESCOTT, E. W. Cobalt- or Nickel-Ore Treatment. U. S. Patent 1,406,595, Feb. 14, 1922; Chem. Abs., vol. 16, 1922, p. 1558.

Arsenical ores of Co or Ni containing Fe are treated in a finely divided state with a current of Cl_2 to volatilize chlorides of Fe and As below 600° C.

214. WILENCHIK, I. W. Separation of Copper From Nickel. U. S. Patent 1,703,329, Feb. 26, 1929, appl. Apr. 16, 1928; British Chem. Abs., 1929, p. 399B.

Copper and nickel alloys are fused with sulfur, sodium sulfate, calcium sulfate, and coke. When the solution has settled, two layers are obtained; the lower is nickel sulfide and the upper sodium-copper sulfide.

SMELTING TO FERROALLOYS

215. BORCHERS, W. Separating Iron and Nickel From Copper Mattes. Canadian Patent 207,476, Jan. 11, 1921; Chem. Abs., vol. 15, 1921, p. 665.

Matte is smelted with lime in a furnace lined with carbonaceous reducing material; the iron and nickel sulfides are first reduced to a considerable extent, then ferronickel is formed by adding more C.

216. BORCHERS, W., AND THILGES, E. Separating Iron and Nickel From Copper in Sulfide Ores, Matte, Etc. U. S. Patent 1,152,699, Sept. 7, 1915; Chem. Abs., vol. 9, 1915, p. 2760.

The material is smelted with an excess of lime flux and just enough C to reduce the Ni and Fe, and gradual reduction is effected by heating. The CaS retards separation of Cu, and an Fe-Ni alloy is obtained that is virtually free from Cu.

217. CARPENTER, FRANKLIN R. Making Ferro-Nickel and Nickel-Steel. U. S. Patent 922,425, May 18, 1909; Chem. Abs., vol. 3, 1909, p. 1980.

Sulfide Cu-Ni-Fe ores are subjected to an oxidizing roast to oxidize the Ni and Fe, the Cu is chloridized and leached out, then the remaining ore is smelted to produce ferronickel or Ni steel.

218. ZARHAROV, V. V. [Methods of Transforming Nickel Matte Into Metal and Ferro-Alloys.] Tsvetnye Metal., No. 1, January 1931, pp. 41–61, 6 figs; Eng. Index, 1931, p. 960.

Discusses profitable methods for working Ural and Caucasian ores. Such ores contain 0.5 to 2.9 percent nickel.

CARBONYL PROCESSES

GENERAL

CARBONYL FORMATION OR PREPARATION

219. FRIERZ, H. E. Extraction of Nickel as Carbonyl. British Patent 4,249, Feb. 19, 1913; Chem. Abs., vol. 8, 1914, p. 2668.

In the extraction of nickel as carbonyl from a mixture of metals, reduced from their oxides by gas containing CO, contact with CO is avoided while the temperature is lowered to enable carbonyl to form. A mixture of Cu and nickel oxides, obtained by roasting the mixture at a temperature of 680°–720° C. and treating it with H_2SO_4 to remove any sulfate, is reduced with producer gas at a temperature preferably above 280° C. but not exceeding 500° C. Hydrogen is passed through the reduction chamber to displace all CO, then the temperature is reduced to 50° C., and pure CO is passed over the metals. The reduction chamber may be evacuated before cooling.

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220. INDUSTRIAL CHEMISTRY. Nickel Extraction by Mond Process. Vol. 10, No. 114, July 1934, pp. 253–264; Eng. Index, 1934, p. 743.

Describes the work at the Clydach refinery of the Mond Nickel Co. near Swansea, Wales. Gives a flow-sheet showing how volatile nickel carbonyl is formed and dissociated into metallic nickel and carbon monoxide.

221. JOHNSON, J. Y. (assigned to I. G. Farbenind., A. G.). Manufacture of Cobalt Carbonyl. British Patent 298,714, July 28, 1927, addition to British Patent 250,132; British Chem. Abs., 1926, p. 487, 1929, p. 54B.

Metallic cobalt or reduced cobalt ore is treated with carbon monoxide at high temperature and pressure (for example, 150°–170° C. and 200 atm.). The bulk of the cobalt carbonyl is separated before the pressure is released at not less than 50° C. The remainder is separated by passing the ore through a solvent or by cooling it to a lower temperature in an apparatus in which the narrow parts are maintained above 50° C. by the hot reaction gases.

222. ———. (assigned to I. G. Farbenind., A. G.). Production of Cobalt Carbonyl. British Patent 307,112, Dec. 3, 1927; British Chem. Abs., 1929, p. 393B.

Increased yields are obtained in manufacturing cobalt carbonyl from cobalt and carbon monoxide by excluding oxidizing agents during preparation of the metal and by passing the carbon monoxide over a catalyst, consisting of an oxide of manganese or copper or a mixture of these oxides, to remove free oxygen.

223. TASSILLY, E., PÉNAU, H., AND ROUX, E. [The Preparation of Nickel Carbonyl.] Bull. soc. chim., vol. 29, 1921, pp. 862–865; Chem. Abs., vol. 16, 1922, p. 1542.

If NiO is reduced by H_2 at 400° C. and the resulting Ni treated with CO from the action of H_2SO_4 on NaOOCH, the best temperature for the reaction is 45° C. under a pressure of 3 cm. of Hg. The best rate for running in CO is 1 liter in 5 or 10 minutes, as it is impossible to condense the $Ni(CO)_4$ faster. A mixture of 50 grams NiO and 80 grams pozzolana, reduced with H_2 and treated with 48 grams CO, yielded 27 grams $Ni(CO)_4$.

MATTES AND METALLURGICAL PRODUCTS

224. MOND NICKEL CO., LTD., AND GRIEB, C. M. W. Production of Nickel Carbonyl. British Patent 347,208, Jan. 16 and July 5, 1930; British Chem. Abs., 1931, p. 632B.

In reducing roasted Ni–Cu matte by producer gas in the Mond process, a small quantity of $NiSO_4$ is added to the charge or a small quantity of SO_2, H_2S, or COS to the reducing gas to produce a reduced material containing 0.2–0.5 percent S as sulfide. Subsequent treatment of the material in volatilizers gives a very high yield of $Ni(CO)_4$, even when much CO is present.

225. SCHLECHT, LEO, AND KEUNECKE, EMIL (assigned to I. G. Farbenind., A. G.). Nickel and Cobalt Carbonyls. Canadian Patent 283,414, Sept. 18, 1928; Chem. Abs., vol. 22, 1928, p. 4212.

Cobalt and nickel carbonyls are produced by roasting cobalt speiss with air and steam and treating it with H_2 at 400° C., leaching the product with $(NH_4)_2CO_3$ solution saturated with gaseous NH_3, expelling the NH_3 by heating, and precipitating the metals as hydroxides and basic carbonates by dilution. Then the product is reduced with dry H_2 at 350° C., and the resulting metal is treated with CO at 150° C. under a pressure of 200 atmospheres.

PYRO STUDIES

NONOXIDES

226. BORNEMANN, K. [The Constitution of Nickel Matte.] Métallurgie, vol. 5, Jan. 22, pp. 61–68; Chem. Abs., vol. 2, 1908, p. 2367.

The author disproves the assumption that nickel matte always contains NiS and never Ni_2S. When little or no FeS is present, the matte contains Ni_2S_2 and free Ni. When considerable FeS is present, the matte contains Ni_3S_2 provided there is sufficient S, otherwise Ni_3S is formed.

227. BROWNE, D. H. Behavior of Copper Matte and Copper Nickel Matte. Bull. Am. Inst. Min. Eng., vol. 40, p. 285; Chem. Abs., vol. 4, 1910, p. 3184.

An investigation of the behavior of Cu–Ni mattes in the bessemer converter has led to the following conclusions: (1) Nickel does not replace Fe in the matte; (2) nickel and copper alloys act in the matte blow like one metal; and (3) nickel and copper alloys act in the matte blow exactly as does Cu alone.

228. CRUT, G. [A Study of the Equilibrium by a Static Method in the Reduction by Hydrogen of the Chlorides and Bromides of Nickel and Cobalt.] Bull. soc. chim., vol. 35, 1924, pp. 729–741; Chem. Abs., vol. 18, 1924, p. 2635, 2993.

Previous measurements of the reduction of $NiCl_2$ by H_2 by means of an open-tube manometer were complicated by diffusion of the gases in the system. The measurements were repeated and extended in a new apparatus designed to obviate this difficulty by diminishing the volume of the system outside the heated zone. The solid salt, heated to 445° C. in a constant-volume apparatus by a vapor bath, was exposed to H_2 or HCl and the rate of the reaction followed by noting the pressure change. The equilibrium concentration of gases was determined from the pressure readings and confirmed by analysis of gas samples. Equilibrium was approached from both sides. The equilibrium constants were found to be $K=11.28(11.33)$ for $NiCl_2+H_2=Ni+2HCl$; $K=10.90$ for $CoCl_2+H_2=Co+2HCl$; $-K=12.05$ for $NiBr_2+H_2=Ni+2HBr$; and $K=11.87$ for $CoBr_2+H_2=Co+2HBr$.

229. GUERTLER, W., AND SAVELSBERG. Ueber die Konstitution und Verarbeitung des Nickelsteins und der Nickel Speise. [An Account of the Composition and Processing of Nickel Matte and Nickel Speiss.] Metall. u. Erz, vol. 29, No. 5, 1932, pp. 84–91; Eng. Index, 1932, p. 882.

Discusses the composition and treatment of nickel matte and nickel speiss from calcined iron and nickel sulfides.

CARBONYLS

230. SHINKICHI, HORIBA, AND TAIKEI, RI. [Decomposition of Carbon Monoxide in the Presence of Reduced Nickel.] Bull. Chem. Soc. Japan, vol. 3, 1928, pp. 18–25; Chem. Abs., vol. 22, 1928, p. 1520.

Describes an improved apparatus for the investigation of contact catalysis. The decomposition of CO in the presence of reduced Ni near 230° C. is a unimodal reaction.

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PART III. HYDROMETALLURGICAL

GENERAL

231. Drury, C. W. Cobalt, Its Production and Uses. Trans. Am. Electrochem. Soc., vol. 43, preprint, 1923; Chem. Abs., vol. 17, 1923, p. 2099.

Gives a brief and general description of the ores, metallurgy, and uses of cobalt. Cobalt metallurgy is chiefly a complex wet extraction accomplished by treating ores or a speiss with dilute H_2SO_4 and by precipitating $Co(OH)_3$ with hypochlorite solution after removing impurities.

232. Tyssowski, J. Hydrometallurgical Operations at Cobalt. Eng. Min. Jour., vol. 90, pp. 1253–1258; Chem. Abs., vol. 5, 1911, p. 658.

The author reviews developments in hydrometallurgical processes at Cobalt, where 13 operating mills treat more than 1,000 tons of ore in 24 hours.

HYDROWINNING, NONSPECIFIED ORES

LEACHING

233. Abel, E. [Recovery of Copper and Nickel From Solutions and Residues.] German Patent 443,910, Mar. 28, 1923. Australian Patent, Apr. 8, 1922; British Chem. Abs., 1928, p. 58B.

Residues containing copper and nickel are heated in an atmosphere of hydrogen chloride with a limited supply of air so that the copper is converted mainly into cuprous chloride. The product is leached with hot, dilute hydrochloric acid so that the solution, after cooling, is saturated with both cuprous and nickel chlorides. The insoluble part is leached with a strong solution of a chloride to dissolve the cuprous chloride, and the soluble part is treated with nickel scrap to remove the remainder of the copper.

234. Chemical Age. The Wet Extraction of Cobalt From Poor Ores. Vol. 20, No. 497, Jan. 5, 1929, pp. 1–2; Eng. Index, 1929, p. 469.

Discusses the separation of copper, nickel, and iron in addition to the recovery of cobalt.

235. Hissink, J. J. [Recovery of Nickel From Ores.] French Patent 595,275, Mar. 18, 1925, conv., Mar. 31, 1924; British Chem. Abs., 1926, p. 675B.

Finely divided nickel ores are extracted with gas liquor in the presence of a current of air. When the ore has been heated previously under reducing conditions, it must be allowed to cool in air to reoxidize the ore and render the nickel soluble in the gas liquor.

236. Joseph, T. B. Metal Leaching Process. Canadian Patent 173,452, Nov. 28, 1916; Chem. Abs., vol. 12, 1918, p. 130.

Gold, Ag, Ni, and Cu are extracted from ore by leaching the ore with an aqueous solution of NaCl, HNO_3, or NH_4OH.

237. Rosalt, Hugues. Treating Ores. U. S. Patent 948,827, Feb. 8, 1910; Chem. Abs., vol. 4, 1910, p. 1014.

Ores of Ni, Co, Cu, Au, or W are treated with $MgCl_2$ and O_3, precipitating chloride solutions.

238. Urazov, G., and Romanov, M. M. [Hydrometallurgical Treatment of Ural Nickel Ores.] Tsvetnye Metal., vol. 5, Nos. 8–9, 1930, pp. 1136–1144; Eng. Index, 1931, p. 960; British Chem. Abs., 1931, p. 1056B.

Discusses results of analyses and experimental study of several types of nickel ores, showing the effect of aqueous solutions of sulfur dioxide of various concentrations and of sulfur dioxide gas on nickel ores.

PRECIPITATION AND SEPARATION

239. Barton, Thomas, and McGhir, Thomas Burns. [Separating Cobalt and Nickel.] French Patent 386,623, Jan. 28, 1908; Chem. Abs., vol. 3, 1909, p. 2360; German Patent 222,141, Jan. 28, 1908; Chem. Abs., vol. 4, 1910, p. 2630.

Cobalt and nickel are separated from solutions containing their mixed chlorides by subjecting the slightly acidified solution to fractional crystallization. Limitations are specified.

240. Bernard. [Separating Nickel and Cobalt.] French Patent 354,941, June 5, 1905; Chem. Abs., vol. 1, 1907, p. 386.

An industrial process of separating nickel and cobalt consists of precipitating, successively, the two metals, using hypochlorite that is free from alkali. The cobalt is precipitated first, but the nickel does not precipitate for several hours if the hypochlorite is sufficiently acid. Addition of an insoluble carbonate to the liquor completes precipitation of the cobalt but does not precipitate the nickel.

241. Bryant, P. S. Cobalt Refining at Rainham Works of Murex, Ltd. Inst. Min. and Met., preprint 17, from symposium, Refining of Nonferrous Metals, July 1949, 15 pp.; Metals Rev., vol. 22, 1949, p. 16.

Copper, iron, and cobalt are separated as basic carbonates. The carbonates are calcined to gray or black oxides and purified. The oxides are then reduced to metallic globules and powders. Cobalt is recovered from the leach liquors.

242. Duisburger Kuperfhütte. Metal Values From Pyrites Cinder. British Patent 276,200, Nov. 18, 1926; Chem. Abs., 1928, p. 2349.

After Cu is precipitated by $Zn(OH)_2$ from the liquor obtained by leaching chlorinated pyrites cinder, any remaining Cu, together with Ni, Co, and precious metals, may be precipitated by zinc or copper hypochlorite.

243. Gates, Walter S., and Dow, Herbert H. (assigned to Ontario Nickel Co., Ltd.). Separating Iron, Nickel, and Copper in Solution. U. S. Patent 956,763, May 3, 1910; Chem. Abs., vol. 4, 1910, p. 2258.

Iron, nickel, and copper are separated from chloride solutions by precipitating them from part of the solution, using $CaCO_3$. After separating the precipitate, it is agitated with another part of the original Fe-Cu-Ni solution until the Fe precipitate is substantially free from Cu and Ni. Filtering separates the Fe precipitate, and the filtrate is returned to still another part of the original solution, to which is added more of the precipitating agent, $CaCO_3$. After the iron is removed the remaining Cu-Ni solution is treated

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with $Ca(OH)_2$ to produce a less soluble precipitate with Cu than with Ni, and the Cu precipitate is removed and agitated with another part of the Cu-Ni solution to dissolve the Ni.

244. GIERTSEN, S. (assigned to Kristiansands Nikkel-Raffineringsverk). [Separation of Metals, Copper, and Nickel.] U. S. Patent 1,575,160, Mar. 2, 1926, appl. Sept. 26, 1921; British Chem. Abs., 1926, p. 370B; Chem. Abs., vol. 20, 1926, p. 1382.

Copper is precipitated from solutions of copper and nickel salts by treating the solutions with bessemerized copper-nickel matte containing less than 10 percent S.

245. KLING, A., LASSIEUR, A., AND LASSIEUR, A. (MME.). [Separation of Zinc and Nickel by Means of Hydrogen Sulfide.] Compt. rend., vol. 180, pp. 517–519; Ann. chim. anal. et chim. appl., vol. 7, 1925, pp. 163–165; Chem. Abs., vol. 19, 1925, p. 2614.

To separate Zn from Ni by means of H_2S in solutions free from added salts, it is necessary to keep the pH value between 1.35 and 2 and continue passing H_2S for a long time. This condition is difficult to maintain.

246. SMITH, S. C. Separation of Cobalt From Solutions Containing Other Materials (e. g., Nickel). British Patent 298,301, July 25, 1927; British Chem. Abs., 1928, p. 893B.

Cobalt is selectively precipitated from solutions of cobalt and nickel salts (particularly sulfates) by lead peroxide without manganese. The cobalt and nickel are completely separated. The operation is conducted at boiling point; cobalt is recovered from the residue by leaching it with sulfuric acid, and the resultant lead sulfate is reconverted into peroxide, the process thus being cyclic. By suitably adjusting conditions the separation may be carried out in two stages, a small amount of cobalt being left in solution at the end of the first operation. The process may be applied to the treatment of ores, mattes, etc.

247. WHITBY, A., AND BEARDWOOD, J. P. Notes on Some Reactions of Zanthates. Jour. Chem. Met. Min. Soc. South Africa, vol. 21, 1921, pp. 199–200; Chem. Abs., vol. 15, 1921, p. 3050.

The alkali salts of xanthic acid are soluble in water, but most other xanthates are insoluble. The Ni salt is easily dissolved by NH_4OH, but the Co and Cu salts are not. On the basis of these facts a method of separating Ni from Co and Cu has been devised.

HYDROWINNING, OXIDIZED ORES

LEACHING

248. EUSTIS, F. A. Treatment of Ores. Canadian Patent 170,673, July 11, 1916; Chem. Abs., vol. 12, 1918, p. 672.

Nickel-bearing Fe ores are divided into two parts, and the soluble Ni compound and dissolved compounds from one part are precipitated on the ore of the other part. This part is then adapted for direct smelting to obtain a Ni–Fe alloy.

249. HOVLAND, H. B., AND FRANKFORTER, G. B. Separating Values From Ores. U. S. Patent 1,335,000, Mar. 30, 1920; Chem. Abs., vol. 14, 1920, p. 1516.

Ore containing oxides, carbonates, or silicates of Cu, Pb, Zn, Mn, Ni, Co, or other metals is treated with dilute H_2SO_4 or other solvent to extract the metal; the dissolved metal is precipitated as sulfide in the presence of the gangue, and the gangue and sulfide precipitate are separated by flotation.

250. MADAGASCAR MINERALS SYNDICATE, LTD. Extracting Nickel From Ores. Norwegian Patent 27,235, Aug. 28, 1916, Chem. Abs., vol. 10, 1916, p. 3058; Swedish Patent 41,557 (addition to 39,491), Nov. 8, 1916; Chem. Abs., vol. 11, 1917, p. 448.

Sulfuric acid extracts Ni from silicates containing other metals, if less acid is used than is required to extract all of the Ni in the ore.

251. OLIVERIA, E. DE [Metallurgy of Nickel.] Ann. acad. brasil. sci., vol. 3, 1931, pp. 75–77; British Chem. Abs., 1932, p. 553B.

The acid liquor obtained from the decomposition by heat and water of south Brazilian coal with a high iron sulfide content dissolves garnierite under mild refrigeration conditions more readily than does H_2SO_4 of the same concentration. Ores containing less than 2.5 percent Ni can be successfully treated.

252. SULMAN, H. L., AND PICARD, H. F. K., Extracting Nickel From Silicate Ores. U. S. Patent 1,091,542, Mar. 31, 1914; Chem. Abs., vol. 8, 1914, p. 1732.

Nickel silicate ores containing Mg and other metals are extracted by heating a paste of the ore to 100°–150° C. with enough H_2SO_4 or HCl to dissolve the Ni and other metals without dissolving all the Mg from the gangue. Metals, other than Ni, are precipitated from the solution by adding $CaCO_3$ and stirring the remaining solution with finely powdered MgO to precipitate Ni as $Ni(OH)_2$. The acid leach liquor, containing salts of Ca or Mg, may be used with 25 percent of fresh acid to extract additional ore.

PRECIPITATION AND SEPARATION

253. MADAGASCAR MINERALS SYNDICATE, LTD., Nickel. French Patent add. 18,721, Mar. 22, 1913, to 463,615, Dec. 21, 1912; Chem. Abs., vol. 8, 1914, p. 2669; Chem. Abs., vol. 9, 1915, p. 1457.

Nickel, as $Ni(OH)_2$, is obtained from the solution of magnesium and nickel sulfates, after oxidation and precipitation of Fe, Al, and Cr by $CaCO_3$, by using pulverulent MgO. The $Ni(OH)_2$ is freed from Mg by heating the solution to a dark red to render the NiO insoluble, then dissolving out the MgO. The $MgSO_4$ crystallizing from the mother liquor is changed to Na_2S for the sulfide precipitation according to the equation, $MgSO_4+2NaCl+4C=MgCl_2+Na_2S+4CO$, or it is converted into MgO with C.

254. SULMAN, H. L., PICARD, H. F. K., AND ROBERTS, A. E., Treatment of Nickel Ore. British Patent 17,131, Mar. 18, 1913; Chem. Abs., vol. 9, 1915, p. 289.

In extracting nickel from ore, the solution of nickel and magnesium sulfates (resulting from use of the process covered by British Patent 27,626, Nov. 30, 1912) is treated with a soluble sulfide such as Na_2S, and the NiS is separated and may be calcined to produce oxide. A suitable precipitant is obtained by crystallizing out $MgSO_4$ from the liquor and calcining it with NaCl and C; by calcining the $MgSO_4$ liquor first with NaCl, then adding C and calcining it again; or by adding NaCl to the $MgSO_4$ liquor and crystallizing out Na_2SO_4, which is then calcined with C.

HYDROWINNING, NON-OXIDIZED ORES

LEACHING

255. CARRICK, JAMES T. Treatment of Pyritic Copper and Copper-Nickel Ores. U. S. Patent 947,789, Feb. 1, 1910; Chem. Abs., vol. 4, 1910, p. 1012.

The crushed ore is digested with HCl in a vacuum

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until the Fe and Ni are substantially dissolved. The liquor is withdrawn; Fe is precipitated therefrom by NH_4OH and oxidation; the precipitate is removed, and Ni is precipitated by $Ca(OH)_2$. The residue containing copper sulfide is oxidized with water and air and the resulting $CuSO_4$ leached out of the ore.

HYDROTREATMENT OF MATTE AND SPEISS

256. BARTH, OTTO. [The Treatment of Cobalt-Nickel Solutions.] Metall. u. Erz., vol. 16, 1919, pp. 267–273; Chem. Abs., vol. 14, 1920, p. 3052.

Arsenic is first removed by roasting, and the product is concentrated by smelting. The concentrated speiss is then sintered with soda, finely ground, and treated with acid (preferably HCl). The acid is first heated in an earthenware vessel, then the powder is added. The metals dissolve in the following order: Pb, Cu, Ni, Co, As, Sb, and Fe. Diluting the solution will precipitate a large part of the Pb, Ag, Sb, and As. The solution now contains mainly Cu, Co, Ni, and Fe, the latter in the ferric state with HCl. There are several methods for treating the solution: (1) Cementation of Ag by metallic Cu and Cu by Fe; (2) precipitating Cu with H_2S or Cu, Co, Ni, and Fe^{III} with Na_2S and heating the solution, thus redissolving NiS and CoS, and (3) precipitating Fe^{III}, Al, Cu, Co, Zn, Ni, Ca, and Mg with alkalies or alkaline earths.

257. BARTH, OTTO. [Working Up a Roasted Cobalt-Nickel Speiss, Rich in Lead.] Métallurgie, vol. 9, pp. 199–216; Chem. Abs., vol. 6, 1912, p. 1732.

The speiss is crushed and given an oxidizing roast to eliminate the As. Then it is roasted in an atmosphere of air and SO_2 at 500° to 600° C. and finally in air alone at 600° C. The sulfatized material is leached with water, thus removing the Cu and most of the Ni-Co and Ag. The Ag is precipitated by metallic Cu, the Cu by Fe, and the Fe by milk of lime. The Fe precipitate is treated with hot NH_4Cl solution to dissolve any associated Ni and Co and chlorides of these metals, and finally the residue is converted to sulfates by boiling it with H_2SO_4. The residue from the first leaching is fused with galena and coal, giving Pb, speiss, and slag. The Pb goes to desilverizing processes, the speiss back to the speiss roasting, and the slag to the sulfatizing roast.

258. CARRICK, JAMES T., Wet Process for the Treatment of Nickeliferous Mattes. British Patent 21,164, Oct. 7, 1908; Chem. Abs., vol. 4, 1910, p. 2086.

The iron and nickel in nickeliferous mattes are separated by treating the mattes with a chloride solution for a prolonged period at normal temperature. A black magnetic ferroferric precipitate is formed from which Ni may be recovered.

259. CHEMICAL INDUSTRY. The Manufacture of Nickel by the Mond Nickel Co., Ltd. Vol. 46, Apr. 29, 1927, pp. 386–391; Eng. Index, 1927, p. 568.

The application of this process is comparatively simple in the laboratory, but its amplification into economical works operation is quite difficult. The matte (a mixture of nickel sulfide and copper sulfide) is crushed and roasted, yielding a mixture of impure oxides. This mixture is treated with enough sulfuric acid to dissolve most of the copper but leave the nickel unaffected. The copper sulfate solution is filtered off and allowed to crystallize. The process is continuous and virtually automatic.

260. DHAVERNAS, J. Extracting Nickel from Nickel-Copper Matte. U. S. Patent 1,266,775, May 21, 1918; Chem. Abs., vol. 12, 1918, p. 1760.

Copper and nickel matte is partly oxidized by roasting, partly reduced to metal, and treated with a neutral or slightly acid Cu solution to dissolve Ni. The solution thus obtained is treated with metallic Ni to precipitate the small amount of Cu that also may have been dissolved.

261. ———. Separating Nickel From Nickel-Copper Alloys. U. S. Patent 1,273,465, July 23, 1918; Chem. Abs., vol. 12, 1918, p. 1870.

Copper and nickel matte is partly oxidized by roasting, then reduced; the reduction product is treated with a slightly acid Cu solution to dissolve the Ni, and the resulting solution is treated with metallic Ni to precipitate the Cu remaining in the solution. The solution of Ni salts is drawn off and Ni recovered therefrom.

262. ———. Separating Nickel From Nickel-Copper Mattes. Canadian Patent 195,990, Jan. 13, 1920; Chem. Abs., vol. 14, 1920, p. 530.

The matte is roasted to remove part of the S; the resulting oxides are reduced to metallic form and treated with an acid to dissolve the Ni. Any Cu in the solution is precipitated by adding metallic Ni, then the solution of Ni salts is treated to yield metallic nickel. It is desirable to have about 8 percent S in the roasted matte.

263. HAGLUND, G., Recovering Copper and Other Metals. U. S. Patent 1,375,631, Apr. 19, 1921; Chem. Abs., vol. 15, 1921, p. 2620.

Copper and nickel are recovered from matte or similar granular material by treating the material with an acid, such as H_2SO_4, to dissolve the Cu and Ni and form a neutral solution. The treatment is continued after the neutral solution is formed until the Cu is cemented out by the Ni. A pure solution of the Ni is obtained, from which the Ni may be recovered by electrodeposition.

264. ———. Treatment of Copper-Nickel Matte. Canadian Patent 226,153, Nov. 21, 1922; Chem. Abs., vol. 17, 1923, p. 7207.

Copper and nickel matte is treated until most of the Ni has been changed to metal. Part of the matte is treated with acid and air, and the Cu from the resulting solution is cemented out on another part of the matte.

265. HARSHAW, W. J., AND HOMER, G. L. (assigned to Harshaw Chemical Co.). Extraction of Copper-Nickel Matte. U. S. Patent 1,729,423, Sept. 24, 1929, appl. Apr. 28, 1926; British Chem. Abs., 1929, p. 1019B.

The matte, after being ground, is leached with acid, lightly roasted, and leached again with acid.

266. HYBINETTE, N. V., Refining Copper and Nickel Matte. U. S. Patent 1,577,422, Mar. 15, 1926; Chem. Abs., vol. 20, 1926, p. 1586; British Chem. Abs. 1926, p. 547B; Canadian Patent 229,457, Mar. 6, 1923; Chem. Abs., vol. 17, 1923, p. 1948.

Copper is cemented on bessemerized copper and nickel matte, from a copper and nickel sulfate solution, and the remaining matte and cement copper are roasted then leached with H_2SO_4 to form a $CuSO_4$ solution. The leached residue is reduced, dissolved to form a copper and nickel solution, and Cu from this solution is cemented on other bessemerized matte.

267. LANGER, C., AND LANGER, O., Refining Nickel-Copper Matte. Canadian Patents 182,613 and 182,770, Mar. 5, 1918; British Patent 109,402, Mar. 17, 1917; U. S. Patent 1,291,030, Jan. 14, 1919; Chem. Abs., vol. 12, 1918, pp. 37, 1045, and vol. 13, 1919, p. 835.

The metals are converted to oxides and treated with concentrated H_2SO_4 at approximately 150° C. The

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resulting sulfates are dissolved in water, and the Cu is precipitated with finely divided Ni. The Ni is recovered by electrolysis.

268. LATHE, F. E., Refining Nickel-Copper Matte. Canadian Patent 279,756, May 1, 1928; Chem. Abs., vol. 22, 1928, p. 2735; U. S. Patent 1,756,092, Apr. 29, 1930 (*see* British Patent 303,066, 1930; British Chem. Abs., 1930, pp. 64, 565B).

Nickel and copper matte is refined by retaining in the matte considerable FeS and rapidly cooling the matte to increase the rate and completeness of solution of the nickel sulfide. The matte is leached with acid to dissolve the nickel sulfide.

269. ———. Lathe's Nickel Refining Process. Mech. Eng., vol. 52, No. 2, 1930, p. 156 (*see* Eng. Index, 1929, p. 1282; and Canadian Chem. and Met., vol. 13, June 1929, p. 12); Eng. Index, 1930, p. 1201.

Describes new method of separating nickel from copper and precious metals in a nickel-copper matte. The solubility of the nickel in the matte is aided by granulating the liquid matte in cold water. Discusses commercial refining processes for ordinary Sudbury mattes, as covered by Canadian Patent 279,756.

270. MACIVOR, RALPH W. E. (assigned to Metals Extraction Corp., London, England). Extracting Nickel. U. S. Patent 846,492, Mar. 12, 1907; Chem. Abs., vol. 1, 1907, p. 1335.

Ground nickel ore or matte is heated with magnesium chloride, then leached for nickel chloride.

271. MCKECHNIE, A., AND BEASLEY, F. G. [Treatment of High-Grade Nickel-Copper Matte.] German Patent 247,968, July 16, 1911; Chem. Abs., vol. 6, 1912, p. 2734; U. S. Patent 1,047,825, Dec. 17, 1912; Chem. Abs., vol. 7, 1913, p. 963.

High-grade nickel-copper matte, virtually free from Fe, is treated in a closed vessel with dilute H_2SO_4 or HCl under pressure and at a high temperature (6 to 7 atm. and 160° C.) The acid acts quickly on the nickel sulfide, forming soluble $NiSO_4$ or $NiCl_2$ and H_2S, which precipitates any Cu in the solution as CuS with the CuS introduced as such. Roasting the crude product hastens the reaction; however, roasting should not be carried too far.

272. PAWEL, G. W., AND REKATE, E. A. Treating Rich Nickel-Copper Matte. U. S. Patent 1,276,809, Aug. 27, 1918; Chem. Abs., vol. 12, 1918, p. 2080.

An easily soluble matte, rich in Cu and Ni, is prepared by dilution or extensive bessemerizing, and the matte is finely ground and treated with hot solutions of strong H_2SO_4. Nickel salts are crystallized from the resulting solution and may be used to produce copper-free metallic Ni. Copper and precious metals are recovered from the residue of the matte by any well-known method. The nickel sulfate crystals may be roasted and the SO_3 released in this process absorbed in water to regenerate H_2SO_4 for treating additional matte.

273. PEEK, ROBERT L., AND HYBINETTE, N. V. Refining Copper Nickel Matte. Canadian Patent 220,718, July 11, 1922; Chem. Abs., vol. 16, 1922, p. 2838.

Disintegrated bessemerized copper and nickel matte is roasted and leached with H_2SO_4 solution; the leached material is reduced, and the Cu from the copper and nickel solution is cemented out on an excess of the reduced material at a temperature little above normal. The cementation may be repeated on fresh parts of the solution. The Ni is separated by electrolysis.

274. PEEK, R. L., AND TORELL, T. F. Refining Copper and Nickel Matte. U. S. Patent 1,569,137, Jan. 12, 1926; Chem. Abs., vol. 20, 1926, p. 735.

In treating bessemerized Cu and Ni matte, Cu is separated from copper and nickel sulfate solutions by cementation upon an excess of the matte. Most of the Cu is removed from the partly exhausted matte, and a copper and nickel sulfate solution is produced from the residue for treating more bessemerized matte.

275. SHULER, DARIUS P. Separating Nickel and Copper From Mattes. U. S. Patent 967,072, Aug. 9, 1910; Chem. Abs., vol. 4, 1910, p. 2924.

Nickel and copper are separated from mattes by finely dividing the matte and treating it with dilute H_2SO_4 to dissolve part of the Ni. Treating the matte again with dilute H_2SO_4 dissolves out virtually all of the Ni. Enough H_2S is maintained in the solutions to prevent the Cu from being dissolved.

276. THE METALS EXTRACTION, LTD. [Nickel From Nickel Ores or Roasted Copper Matte.] German Patent 187,415, Feb. 8, 1906; Chem. Abs., vol. 2, 1908, p. 731.

A process of obtaining nickel from nickel ores or roasted copper matte consists of heating the finely ground ore or matte to approximately 250° C. with $MgCl_2$, then extracting the mixture with water or digesting it in a $MgCl_2$ solution under pressure. The ready transposition of the $MgCl_2$ into oxychloride and HCl results in a nickel chloride solution which is reduced by the known method.

277. UNITED STATES NICKEL CO. Extracting Nickel. British Patent 122,335, Apr. 11, 1918; Chem. Abs., vol. 13, 1919, p. 1299.

Copper and nickel matte is roasted until it contains 8 to 12 percent S, then reduced by gases, coke, or other means. If the matte contains little S, roasting is unnecessary. The reduced product is leached with H_2SO_4, HCl, or $CuSO_4$ to dissolve the Ni and NiS without dissolving the Cu. Partly roasted matte or metallic Ni may be added to prevent solution of Cu or to ensure precipitation of any Cu that may have been dissolved. The solution of Ni salt may be treated for extraction of Ni by adding CaO and subsequently reducing the hydroxide.

278. WELLS, H. L. Separation of Copper, Nickel, Etc., From Copper-Nickel Matte. U. S. Patent 940,292, Nov. 16, 1909; Chem. Abs., vol. 4, 1910, p. 437.

Matte rich in sulfides of Cu and Ni is pulverized and treated with hot HCl solution (containing at least 25 percent HCl); the resulting solution contains the Ni and the residue the Cu. The residue is treated progressively with HCl, and the nickeliferous solution is treated with matte and its residues until the HCl has been exhausted by conversion into $NiCl_2$ and the matte freed of Ni.

279. WELLS, H. L., AND KING, T. C. Extracting Nickel From Matte. U. S. Patent 1,067,698, July 15, 1913; Chem. Abs., vol. 7, 1913, p. 2923.

Nickel is extracted from matte as chloride by treating the finely divided matte with HCl and electrolyzing the solution to deposit Ni and produce Cl_2. Treating the Cl_2 with H_2S regenerates HCl, which is absorbed in water.

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STUDIES; EQUILIBRIA; SOLUTIONS; STRUCTURES OF SALTS AND METALS

AMMINES AND AMMONIA COMPOUNDS

280. GROTHE, H. Beiträge zur Trennung von Kobalt und Nickel in wässeriger Lösung. [Contribution to the Separation of Cobalt and Nickel in an Aqueous Solution.] Metall. u. Erz, vol. 30, No. 22, Nov. 2, 1933, pp. 449–455; Eng. Index, 1934, p. 742.

Nickel and cobalt were separated and recovered from an aqueous solution. The difference in the reaction of cobalt- and nickel-salt solutions in the presence of ammonia is compared as a basis for separation using hypochlorite.

OTHER MATERIALS

281. VESTERBERG, K. A. [The Hydrolysis of Cobalt and Nickel Acetates.] Ztschr. anorg. allgem. Chem., vol. 99, 1917, pp. 22–24; Jour. Chem. Soc., vol. 112, pp. 11, 263; Chem. Abs., vol. 11, 1917, p. 2987.

The hydrolysis of these acetates was determined by extraction. At 18° C., $Co(OAc)_2$ is 0.19 percent hydrolyzed in 0.5 N solution, 0.16 percent in 0.2 N solution; $Ni(OAc)_2$ is 0.16 and 0.38 percent hydrolyzed with the same dilutions. The fact that $Ni(OAc)_2$ appears to be more strongly hydrolyzed in the 0.5 N solution is attributed to the salting out of AcOH by the more concentrated solution.

HYDROPURIFICATION AND HYDROSEPARATION

CEMENTATION AND DISPLACEMENT REACTIONS

282. BAGHADASARIAN, A. B. Precipitation of Nickel From Solution. U. S. Patent 1,671,004, May 22, 1928; Chem. Abs., vol. 22, 1928, p. 2445.

After impurities have been removed from a nickel-bearing solution, zinc is added to precipitate most of the nickel. The nickel precipitate is removed, and the remaining solution is maintained at approximately boiling point. Additional zinc is added to complete precipitation of the nickel.

283. FRENTS, G. S., AND KREINGAUZ, B. P. [Kinetics of Deposition of Cobalt and Nickel From Aqueous Solution by Metallic Zinc.] Izvest. Akad. Nauk S. S. S. R. Otdel. Tekh. Nauk, Dec. 1947, pp. 1705–1712; Metals Rev., vol. 21, May 1948, p. 24.

Experimental results show that deposition takes place most efficiently at a pH of 3.5 to 4.0. The process of deposition proceeds more rapidly at higher concentrations of metal in solution. Cobalt is deposited twice as fast as nickel under the same conditions.

284. HAGLUND, G. Separating and Refining Copper and Nickel. Canadian Patent 224,229, Oct. 3, 1922; Chem. Abs., vol. 16, 1922, p. 4180.

Copper and nickel sulfides are treated with H_2SO_4. The resulting neutral solution is used to treat granules containing metallic Cu and Ni; Cu is cemented out by the Ni and a pure $NiSO_4$ solution formed. The Ni is electrodeposited.

285. HYBINETTE, N. V., AND PEEK, R. L. Refining Copper-Nickel Mattes. U. S. Patent 1,382,361, June 21, 1921; Chem. Abs., vol. 15, 1921, p. 3444.

Nickel and copper sulfate solutions, such as those from roasted mattes, and H_2SO_4 are brought into contact with an excess of finely divided Ni at a temperature of 40°–60° C., and the Cu is separated by cementation.

286. LIENHARDT, W. S., Recovering Nickel From Solutions. U. S. Patent 1,592,306, July 13, 1926; Chem. Abs., vol. 20, 1926, p. 3153.

To precipitate Ni from solutions containing H_2SO_4, metals such as iron are used, which are higher than Ni in the electromotive series. Before the precipitation, NaCl or other chloride compound is added to facilitate precipitation of Ni. United States Patent 1,592,307 specifies a similar process using Na_2SO_4 or other sulfate of a metal not precipitated by iron.

MISCELLANEOUS HYDROOPERATIONS

287. SCHOPPER, W. [The Precipitation of Metallic Salts From Solution by Calcium Carbonate and Calcium Hydroxide.] Metall. u. Erz, vol. 21, 1924, pp. 17–22; Chem. Abs., vol. 18, 1924, p. 1636.

Complete separation of Fe, Cu, Zn, As, and Ni is suggested by treating metallic salts with H_2SO_4 then salt, followed by fractional precipitation using quicklime, limestone, and Na_2CO_3.

288. UDY, M. J., AND RALSTON, O. C. Separating Nickel From Cobalt. U. S. Patent 1,365,358, Jan. 11, 1921; Chem. Abs., vol. 15, 1921, p. 931.

Cobalt is precipitated from cobalt and nickel solutions by subjecting the solution to the simultaneous action of Cl_2 and $CaCO_3$ at about 0°–4° C., which is below the temperature at which Ni precipitates.

PURIFICATION OF MATERIALS FOR ELECTROLYSIS

289. GEPP, H. W. Separating Cobalt From Zinc Solutions. Canadian Patent 210,192, Apr. 5, 1921; Chem. Abs., vol. 15, 1921, p. 1661.

Cobalt is separated from zinc solutions for electrodeposition of the Zn by precipitating the cobalt with PbO in the presence of a Mn compound.

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PART IV. ELECTROMETALLURGICAL

ELECTROWINNING

ELECTRORECOVERY OF METALS

290. BRASS WORLD, Electrolytic Nickel Smelting in Norway. Vol. 7, p. 429; Chem. Abs., vol. 6, 1912, p. 574.

Norway has extensive deposits of Ni ores that contain as much as 2 percent Ni. The Ni ore is smelted into matte, which contains 40 percent Ni and 25 percent Cu, and the matte is refined electrolytically at Christianssand. The matte is used as the anode in a weak acid bath to recover the Cu. The electrolyte is purified with H_2S, then the Fe is precipitated and the Ni deposited electrolytically with insoluble anodes.

291. CARRERAS, R. S. Treatment of Complex Ores of Copper, Cobalt, and Nickel. British Patent 336,584, July 10, 1929; British Chem. Abs., 1931, p. 28B.

The ore is dissolved in dilute sulfuric acid containing 5 percent of sodium chloride, and the solution is electrolyzed to recover copper using insoluble anodes. Then the electrolyte is evaporated fractionally to recover cobalt and nickel sulfates, from which the metals are recovered by electrolysis.

292. CHALAS, ADOLPHE. Nickel From Siliceous Ores. U. S. Patent 887,735, May 12, 1908; Chem. Abs., vol. 2, 1908, p. 2671; French Patent 393,991, Sept. 5, 1908; Chem. Abs., vol. 4, 1910, p. 1716.

Ferronickel is obtained by smelting the ore, casting it into anodes, electrolytically dissolving the anodes, and circulating the dissolved iron through a body of nickel hydroxide until the reagent is exhausted.

293. ———. Recovering Nickel From Nickel-Iron Silicate Ores. British Patent 18,596, Sept. 4, 1908; Chem. Abs., vol. 3, 1909, p. 2293.

Nickel is recovered from nickel-iron silicate ores by smelting the ores to produce ferronickel, casting the alloy into anodes, electrolytically dissolving the anodes, continuously precipitating the dissolved Fe by circulating the electrolyte from the cell in contact with a precipitating agent such as $Ni(OH)_3$, and redepositing the dissolved Ni.

294. ———. Recovering Nickel and Copper From Ores and Mattes. U. S. Patent 947,791, Feb. 1, 1910; Chem. Abs., vol. 4, 1910, p. 1013.

Nickel and copper anodes (formed by smelting a Ni-Cu ore) are electrolytically dissolved in a diaphragm cell containing a NaCl solution. The dissolved Cu is precipitated continuously by circulating the anodic Ni-Cu solution through a filter containing Ni-Cu hydroxides. The purified anodic Ni solution is mixed with the cathodic alkali solution to precipitate the Ni as hydroxide, which is separated by a second filter. Nickel and copper anodes are similarly dissolved in a second diaphragm cell. The Ni-Cu anodic solution is mixed with the alkali cathodic solution, and the resulting Ni-Cu hydroxides are separated by a third filter. This filter is substituted for the first filter when the first filter is filled with $Cu(OH)_2$; the second filter when filled with $Ni(OH)_2$ is replaced by a fourth empty filter, and the third filter is replaced by one filled with Ni-Cu hydroxide.

295. CHEMISCHE FABRIK JOHANNISTHAL, G. M. B. H., AND TROSTLER, F. Electrolytic Treatment of Materials Containing Copper and Nickel. British Patent 283,132, Jan. 4, 1927; Chem. Abs., vol. 22, 1928, p. 3847.

Copper- and nickel-bearing alloys, mattes, or speisses are treated as anodes in neutral or weakly basic electrolyte such as NaCl solution. Copper and nickel hydroxides are precipitated and treated with a solution of a Cu salt, such as the chloride or sulfate (preferably in excess, and repeatedly if required), until the nickel hydroxide dissolves. Lead, when present, remains with the Cu, As, and S.

296. ———. Recovery of Copper and Nickel. British Patent 283,132, Dec. 19, 1927; German Patent, Jan. 4, 1927; British Chem. Abs., 1929, p. 525B.

Copper and nickel alloys, mattes, or speisses are oxidized anodically in slightly alkaline 10 to 20 percent sodium chloride solution to produce an anode slime containing copper and nickel hydroxides. The slime is collected, washed, and digested with copper sulfate solution; the nickel hydroxide dissolves, and an equivalent quantity of copper hydroxide is precipitated. This is collected, washed, and converted into metal by the usual method.

297. CITO, CAMILLO C. A New Process for the Treating of Cobalt-Nickel Ores, Rich in Silver and Arsenic, by Combined Melting and Electrolytic Operations. Trans. Am. Electrochem. Soc., vol. 17, 1910, pp. 239–248; Chem. Abs., vol. 4, 1910, p. 2773.

To obtain a high yield of high-percentage Ag from Co ore, the author devised a special process. The ore is first smelted with enough Cu flux so that the percentage of Cu is two-thirds that of the Ni and Co and at least equal to that of the As, thereby forming an alloy including all of the Ag, Cu, Co, and Ni and most of the As. This alloy is used as the anode in an electrolytic bath of acidified $CuSO_4$ solution at 60° C. The Cu deposits on the cathode, forming a commercial product; Ag with some As precipitates in the slime for subsequent refining; Co, Ni, and most of the As go into solution. The Co and Ni are recovered later by electrolysis, and the As is precipitated as sulfide.

298. COWPER-COLES, SHERARD. Some Notes on the Recovery and Refining of Nickel. Elec. Rev., London, Dec. 23, 1898; Eng. Index, 1896–1900, p. 669.

This article reviews briefly electrometallurgical methods for treating nickel ore.

299. GILLIES, J. H. Recovering Metals From Alloys. Canadian Patent 184,017, Apr. 30, 1918; Chem. Abs., vol. 12, 1918, p. 1273; U. S. Patent 1,260,661, Mar. 26, 1918; Chem. Abs., vol. 12, 1918, p. 1443.

Nickel is recovered from Ni-Cu alloys by passing an electric current from a Ni-Cu anode to a suitable cathode, through an electrolyte containing a Ni salt, and reversing the polarity of the electrodes at such intervals and for such periods as to prevent substantial deposition of Cu upon the cathode.

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300. GOLDBERG, P., Electrodeposition of Copper and Nickel. British Patent 145,600, June 29, 1920; Chem. Abs., vol. 14, 1920, p. 3372.

In treating Cu-Ni alloys or concentrates in chloride solutions, an oxidizing agent, such as Cl_2, is introduced at intervals or continuously, so that the Cu deposited at the cathode equals that dissolved from the alloy which constitutes the anode. The solution may contain HCl or a chloride such as NaCl. Initially, for instance, it may be a solution of 135 grams of crystallized $CuCl_2$ per liter of 25-percent HCl. At a low electric pressure, Cu and Ni dissolve from the anode as subchlorides, no Cu being deposited until a large part of the $CuCl_2$ is reduced. No Cl_2 is added until deposition has brought down the proportion of Cu in solution to about 4 percent. The anode may contain 30 percent of Cu. When the solution is rich enough in Ni, it is treated for the recovery of this metal by known means.

301. GUESS, G. A. Electrolytic Separation of Nickel From Copper. U. S. Patent 1,251,511, Jan. 1, 1917; Canadian Patent 181,038, Dec. 18, 1917; Chem. Abs., vol. 12, 1918, p. 654.

In electrolyzing a solution of nickel sulfate with a Cu-Ni anode, $CaCO_3$ is interposed between the anode and cathode and screened from contact with the cathode to prevent deposition of Cu on the cathode.

302. HARSHAW, W. J. (assigned to Harshaw, Fuller & Goodwin Co.). Separating Cobalt From Nickel. U. S. Patent 1,596,253, appl. Sept. 26, 1924; British Chem. Abs., 1926, p. 885B.

A solution of cobalt and nickel salts is treated with a soluble lead salt and electrolyzed. The lead peroxide formed on the anode reacts with the cobalt salt to form cobaltic hydroxide and regenerates the lead salt.

303. HEBERLEIN, C. Electrodeposition of Nickel. U. S. Patent, 1,389,829, Sept. 6, 1922; Chem. Abs., vol. 16, 1922, p. 28; British Patent 154,471, Aug. 8, 1919; Chem. Abs., vol. 15, 1921, p. 9917.

A slightly acid solution containing a Ni salt, such as $NiSO_4$ solution obtained by treating Ni ore with acid, is electrolyzed and circulated continuously through the cathode compartments of a series of electrolyzing vats in serial order. The insoluble anode compartments of the vats contain a similar circulating liquor, of which part is withdrawn as soon as its acidity has exceeded the optimum acidity in the catholyte and used for preparing additional solution from fresh ore.

304. HYBINETTE, N. V. Electrolytic Recovery of Copper, Zinc, or Nickel. German Patent 285,652, Nov. 8, 1912; Chem. Abs., vol. 10, 1916, p. 563.

The initial material, which contains the metals partly as oxides and partly as sulfides, is extracted and electrolyzed in two steps. First, it is extracted with a solution not too rich in $Fe_2(SO_4)_3$, using electrolytic cells with diaphragms. Then part of the liquor is subjected, in a second phase, to the action of electrolytic cells with diaphragms, increasing the $Fe_2(SO_4)_3$ content. This liquor is used to extract the residual, difficultly soluble metal constituents.

If a sulfidic ore containing about 4 percent Cu is to be worked, the crude material is roasted until 0.5–1.0 percent S remains unoxidized, then extracted and electrolyzed.

305. ———. Separating Copper and Nickel From High-Grade Copper-Nickel Matte. U. S. Patent 1,128,313, Feb. 16, 1915; Chem. Abs., vol. 9, 1915, p. 1009.

Copper and nickel are separated from high-grade copper-nickel matte by electrolyzing a slab of the matte as an anode, then depositing on the slab, by cementation, Cu from a solution containing Cu and Ni sulfates. At the same time the solution is enriched with the Ni in the slab that has been replaced by Cu.

306. ———. Electrolytic Separation of Copper and Nickel. U. S. Patent 1,128,315, Feb. 16, 1915; Chem. Abs., vol. 9, 1915, p. 1009.

The electrolyte is alternately introduced into the top and bottom of the cathode compartment. As a result, less solution is required for circulation through the filter between the cathode and anode.

307. ———. [Separating Nickel From Copper.] Swedish Patent 42,496, May 9, 1917; Chem. Abs., vol. 11, 1917, p. 2642.

The metals are separated by a combined electrolytic and cementation process. The anode, formed of sulfur containing Ni–Cu material, is electrolyzed in acid $NiSO_4$ solution, so that the Ni is deposited on the cathode, whereas the Cu is removed from the solution by cementation on the metal plate containing Ni, Cu, and S.

308. ———. Electrolytic Malleable Nickel and Nickel Alloys. Canadian Patent 229,448, Mar. 6, 1923; Chem. Abs., vol. 17, 1923, p. 1926.

The electrolyte is withdrawn from the tank, boiled in the presence of a basic precipitate of Ni, and returned to the tank for further use.

309. LARSON, J. P. A. AND HELME, G. K. L. [Recovery of Zinc, Cobalt, Etc., From the End Lyes of Copper Extraction.] Swedish Patent 34,407, July 24, 1911; Chem. Abs., vol. 7, 1913, p. 3085.

In the recovery of zinc, cobalt, etc., from the end lyes of copper extraction, the end lye is treated with an electric current of 4 to 6 volts to decompose the Zn and Co salts, the strength of current ranging from 2 to 10 a. per $m.^2$ An insoluble anode is used, but no diaphragm is placed between the anode and the cathode. The Zn, Co, and Cu deposit on the cathode; the acid or the Cl_2, not bound by the base, is neutralized with metals, metal oxides, or oxyhydroxides, etc. Finally, the solution is diluted to precipitate the Fe compounds.

310. ROUSSEAU, E. Séparation du nickel et du fer d'avec le chrome par électrolyse. [Electrolytic Separation of Nickel and Iron from Chrome.] Chem. Ind., vol. 13, No. 2, February 1925, pp. 199–201; Eng. Index, 1925, p. 512.

311. SALVELSBERG, W. Neuste Entwichlung und augenblicklicher Stand der elektrolytischen Gewinnung und Raffination der Nickel. [Latest Developments and Present Status of Electrowinning and Refining of Nickel.] Metall. u. Erz, vol. 31, No. 10, May 2, 1934, pp. 222–226; Eng. Index, 1934, pp. 742–743.

Discusses recent developments and present status of electrolyte production and refining of nickel, especially in Germany. Describes processes of the Oxford, International Nickel, and Haglund companies, also the method of electrolytic nickel recovery from a chloride solution used at the Allgemeinen elektro-metallurgischen G. m. b. H. plant in Ems, Germany.

312. SMITH, S. C. Electrolytic Recovery of Metals (Nickel). British Patent 314,579, Mar. 30, 1928; British Chem. Abs., 1929, p. 725B.

Nickel may be recovered from sulfate solutions by electrolysis, using an aluminum cathode and lead anodes, provided that the pH of the solution is maintained between 3.5 and 6.5. This is done by continuous agitation and gradual addition of ammonia, at a temperature above 50° C. to prevent crystallization of nickel ammonium sulfate. The spent electrolyte is evaporated to recover the remaining nickel as the double salt, which is insoluble in saturated ammonium sulfate solution; subsequently, it is further evaporated to recover ammonium sulfate.

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ELECTRODEPOSITION OF METALS

313. Bennett, C. W., Kenny, H. C., and Dugliss, R. P. Electrodeposition of Nickel. Trans. Am. Electrochem. Soc., vol. 25 (advance copy); Jour. Phys. Chem., vol. 18, pp. 373–384; Chem. Abs., vol. 8, 1914, p. 2310.

The efficiency of deposition from a nickel ammonium sulfate solution was increased by using a stationary cathode and a neutral or acid solution. The addition of NH_4OH to the solution also increased the efficiency, especially in the early stages of electrolysis.

314. Garin, M. V. (Nee Bailly). Electrodeposition of Copper or Nickel. British Patent 104,678, Feb. 23, 1917; Chem. Abs., vol. 11, 1917, p. 1933.

In the deposition of Cu or Ni, albuminoid or gelatinous materials, such as albumin, gelatin, and dextrin, are added to the solution, and the cathode is freed from H_2 bubbles by light and soft rubbers of wood, such as cottonwood, coconut fiber, raw or parchmented skin, or wood covered with skin. Such rubbers may be attached to a rod reciprocating in a direction parallel to the axis of the rotary cathode cylinder. Alternatively, small pieces of the rubbing material may float on the electrolyte, from which the rotary cathode emerges slightly. The cathode may be insoluble material, such as Cu. It is nearly surrounded by an insoluble anode, which may be perforated or unperforated Pb. The electrolyte may be a solution obtained by lixiviating roasted Cu ore, and it is charged with SO_2 from the ore or from roasted pyrites before use. Poor, impure solutions can be exhausted of Cu without deposition of spongy Cu or CuS. The acid produced is used for lixiviation.

315. Hughes, W. E. Electrodeposition of Metals: Nickel. Beama, vol. 9, 1921, pp. 137–144; Chem. Abs., vol. 15, 1921, p. 3424.

Presents a detailed review of the electrodeposition of nickel. Many references to the literature are appended.

316. Hybinette, N. V. Electrolytic Isolation of Copper, Zinc, and Nickel. British Patent 5,806, Mar. 7, 1912; Chem. Abs., vol. 7, 1913, p. 2725.

Sulfide ore or other material containing Cu is mixed with 2 to 20 percent of Na_2SO_4, roasted, leached with dilute H_2SO_4, and electrolyzed to deposit the Cu. The Na_2SO_4 promotes conversion of Cu, Zn, and Ni into sulfates and of Fe into insoluble oxide. The anodes may be insoluble, and the spent electrolyte may be used repeatedly for leaching. When the electrolyte contains a large quantity of Na_2SO_4 it is mixed with fresh ore to be roasted. Zinc and nickel that accumulate in the solution may be precipitated by soda or lime or deposited electrolytically. Loss of Na_2SO_4 is compensated by adding NaCl, which is converted into sulfate during roasting. Leaching with acid may be preceded by treatment with water, which dissolves Cu, Zn, and Ni but no Fe; the solution thus obtained is electrolyzed separately.

317. ———. Electrodeposition of Nickel. British Patent, 193,881, Aug. 29, 1921; Chem. Abs. vol. 17, 1923, p. 3647.

Describes a process for depositing Ni in which the electrolyte flows from the cathode chamber to the anode chamber through a filtering diaphragm. Electrolyte containing free H_2SO_4 is supplied to the cathode chamber; the current density, rate of flow, and nature of the diaphragm are such that the electrolyte is rendered almost neutral near the cathode. For example, an electrolyte of $NiSO_4$ containing 50 grams of Ni and 2 grams of free H_2SO_4 per liter is supplied at 50° C.; the excess pressure in the cathode chamber is ½ to 1 inch, producing a flow of about 1 liter per sq. ft. per hour, with a current density of 10 a. per sq. ft.; the acidity of the electrolyte near the cathode is reduced to approximately 0.2 gram per liter. A suitable construction is specified.

318. Johnson, Woolsey McA. Notes on the Electrodeposition of Nickel. Brass World, No. 44509, August 1913; Eng. Index, 1913, p. 150.

Nickel deposited at a high current density will not "curl up."

319. Pedersen, A. Z. Electrodeposition of Nickel, Cobalt, and Other Metals. British Patent 261,592, Feb. 9, 1926; Chem. Abs., vol. 21, 1927, p. 3316.

Cathode molds (composed of or coated with Ni, Co, Fe, Cu, or other metals that are "anodically corrosive") are connected as anodes for a short time to render subsequently deposited metal sheets easily separable. If the current is reversed between successive deposits, overlying sheets of Ni or other deposited metals may be easily separated.

320. Riedel, R. [Electrolytic Separation of Nickel From Its Chloride Solutions.] Ztschr. Elektrochem., vol. 21, 1915, pp. 5–19; Chem. Abs., vol. 9, 1915, p. 1275.

With a carbon anode the current efficiency drops rapidly (linearly) with the acidity (80-percent yield at 0.07 percent HCl or 1 percent $H_2C_4O_2$) and increases with Ni concentration and current density. To obtain metallic deposits that are not spongy or discolored, it is necessary to regulate the current density, which may be higher with free $H_2C_4O_2$ than with HCl and with higher acid and Ni content. In HCl solution, the "poisoning" effect of small quantities of impurities (0.005 percent Pb, 0.025 percent Zn or ferric salt, 0.05 percent Cl_2) may be corrected by changing conditions; in $H_2C_4O_2$ solution the nature of the deposit is much less sensitive to impurities (0.05 percent Pb), and the discoloration due to density is permanent. Studies of the peeling of the deposit or the effect of stirring were not included.

ANODES FOR ELECTROLYSIS

321. Barrows, W. S. Nickel Anodes and Their Uses. Canadian Foundry, vol. 17, 1926, pp. 14–16; Jour. Inst. Metals, vol. 37, p. 625; Chem. Abs., vol. 22, 1928, p. 2328.

Discusses experiments on the wear of Ni anodes and the effects of various impurities. It is much easier to maintain equilibrium between anode and cathode efficiency with low-purity Ni anodes than the high-purity anodes, and a properly cast 90–92 percent anode is better than a poorly cast 95–97 percent anode. Sulfur and copper are both injurious, but red stains on anodes when the bath is idle may be due to Co and not necessarily to Cu. Tin does not improve the quality of an anode; however, it makes the casting easier and, like Si, increases the formation and maintenance of slime on the anodes. Iron and manganese are generally harmful, but Fe is sometimes useful where a white finish is required (as in stove plants). The question of cleaning anodes is discussed. In general, Barrows is against cleaning, as the cost of labor and the loss of Ni usually outweigh the better results.

ELECTROSEPARATIONS

322. Harshaw, W. J. Separating Cobalt From Nickel. Canadian Patent 279,454, Apr. 17, 1928; Chem. Abs., vol. 22, 1928, p. 2720.

A solution of Ni and Co salts is electrolyzed with metallic Pb anodes. The anodes are oxidized to lead oxide, which reacts upon the Co to form $Co(OH)_3$.

323. Zeitschrift für Elektrochemie und angewandte physikalische Chemie. [The Hybinette Process for Separating Copper From Nickel.] Vol. 27, 1921, pp. 61–63; Chem. Abs., vol. 15, 1921, p. 2586.

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In the hydrometallurgical separation of Cu and Ni by electrolysis in a diaphragm cell containing acidulated $NiSO_4$ solution with crude Cu–Ni anode, the concentration of the Cu dissolved from this anode is kept down by circulating the anolyte through an external tank in which the Cu is precipitated by cementation on a partly used anode taken from an electrolytic cell. The preliminary use of the anode in an electrolytic cell is essential, as it gives the plate a surface that causes a spongy, rather than a dense, deposit of Cu to form, thus maintaining the precipitating efficiency of the plate. Special means are provided to prevent high concentration of Cu in the anolyte, which would cause an impure precipitate of Ni to form owing to penetration into the cathode compartment of the cell by the solution if high in Cu.

ELECTROLYSIS STUDIES

OVERVOLTAGE, VOLTAGE, AND CURRENT DISTRIBUTION

324. Blikslager, H. J. [Contribution to the Knowledge of the Electrochemistry of Molten Salts.] Rec. trav. chim., vol. 46, 1927, pp. 305–327; Chem. Abs., vol. 21, 1927, p. 2836.

The separation of Co and Ni alloys by electrolysis of fused mixtures was tested, and the resulting alloys contained as much as 15.4 percent Co. Iron and cobalt alloys also were obtained, but no Mn and Fe alloys as Fe alone separated.

MISCELLANEOUS STUDIES

325. Emelianova, N. V. [Researches With the Dropping Mercury Cathode. VII. Nickel and Cobalt.] Rec. trav. chim.; vol. 44, 1925, pp. 528–548; Chem. Abs., vol. 19, 1925, p. 2905.

Nickel and cobalt salts were dissolved in neutral, acid, ammoniacal, and alkali cyanide solutions. The voltages at which Ni salts are decomposed on electrolysis, with the dropping Hg cathode, show abnormal changes with dilution, and the primary cathodic process consists of reducing bivalent Ni to univalent Ni.

326. Georgi, K. Über das anodische Verhalten des Kobalts. [Concerning the Anodic Behavior of Cobalt.] Ztschr. Elektrochem., vol. 39, No. 4, April 1933, pp. 209–219; Eng. Index, 1933, p. 237.

Experiments performed on the anodic behavior of cobalt are discussed, and the results are recorded in curves and tables.

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PART V. MISCELLANEOUS

RECOVERY AS A BY-PRODUCT

327. Skowronski, S. Refinery Production of Nickel Salts Used for Electroplating. Eng. Min. Jour., vol. 128, No. 14, Oct. 5, 1929, p. 544; Eng. Index, 1929, p. 1282.

Discusses byproducts of electrolytic copper refining.

RECOVERY FROM SCRAP SOURCES

SPENT CATALYSTS

328. Uyeno, S. [Recovery of Nickel Catalyzer.] Japanese Patent 32,375, Mar. 14, 1918; Chem. Abs., vol. 12, 1918, p. 2255.

The fats and oils are dissolved out of the Ni, which is then dissolved in HNO_3 and roasted to NiO. This oxide is then reduced to Ni with H_2, C_2H_2, or other suitable reducing agent.

SCRAP METALS, ALLOYS, AND COATINGS

329. Breuning, E. Recovery of Nickel From Compound Sheets of Copper and Nickel. British Patent 274,064, June 27, 1927; German Patent, July 10, 1926; British Chem. Abs., 1928, p. 412B.

Copper may be dissolved from the surface of a nickel sheet by treating it at 80° C. with neutral ferric sulfate solution in the presence of an oxidizing agent such as air, oxygen, ozone, or a persulfate and an oxygen carrier, such as ceric sulfate. The nickel becomes passive and remains unattacked.

330. Ellenberger, E. [Recovering Copper, Nickel, or Zinc From the Surface of Iron Scrap.] Netherland Patent 1,751, Jan. 2, 1917; Chem. Abs., vol. 11, 1917, p. 448.

The coating is dissolved by an ammoniacal solution of the NH_4 salts of inorganic acids, preferably carbonate, and air.

331. McKechnie, A. Separating Nickel From Alloys. U. S. Patent 1,381,720, June 14, 1921; Chem. Abs., vol. 15, 1921, p. 3444.

Cupronickel alloy or scrap material containing metallic nickel and copper is melted and oxidized in a basic reverberatory furnace. The treatment is continued until all or a large part of the Ni is volatilized out of the furnace in the form of oxide, which is collected and reduced to metallic nickel.

332. Partridge, A. R. Reclaiming Copper and Other Metals. U. S. Patent 1,352,912, Sept. 14, 1920; Chem. Abs., vol. 14, 1920, p. 3399.

Materials from which the metal is to be reclaimed are heated to a melting point, cooled, and allowed to "sweat" and trickle down an incline, then brought into contact with O_2 to effect purification. The process is also adapted to the recovery of Pb, Ni, V, W, Ag, and Au.

333. Szschaschel, Hans. Die Verarbeitung von Neusilberschrott nach verschiedenen Verfahren. [Different Methods for Processing Nickel-Silver Scrap.] Ztschr. Erzbergbau u. Metallhüttenw., vol. 2, June 1949, pp. 161–168, July 1949, pp. 212–214; Metals Rev., vol. 22, October 1949, p. 40.

Converter and electrolytic processes for extracting Cu, Ni, and Zn from scrap are evaluated. Discusses carbonyl process, vaporization process, and distillation melting.

SPENT LIQUORS

334. Larson, J. P. A., and Laur, G. K. Zinc, Cobalt. German Patent 280,525, Nov. 24, 1912; Chem. Abs., vol. 9, 1915, p. 1880.

Zinc, cobalt, and other values are electrodeposited from waste Cu liquors, at the same time rendering the liquors harmless.

335. Richter, C. [On Some Experiments for Recovery of Copper and Nickel From Waste Products in Nickel Plating.] Ztschr. Elektrochem., vol. 9, 1906, p. 185; Chem. Abs., vol. 1, 1907, p. 690.

Copper and nickel are recovered from waste products in nickel plating.

REFINING OF METAL, PYROMETALLURGICAL

336. Lamothe, J. de Fonds. Pure Nickel From Impure Oxides of Nickel. Canadian Patent 217,517, Apr. 2, 1922; Chem. Abs., vol. 16, 1922, p. 1736; U. S. Patent 1,480,212, Jan. 8, 1924; Chem. Abs., vol. 18, 1924, p. 811.

Finely divided impure NiO is partly reduced with charcoal, and the finely powdered material is lixiviated with weak solutions of HCl and HF; then it is agglomerated into blocks, which are calcined with powdered charcoal and lime.

337. McKechnie, A. Separating Nickel From Nickel-Copper Alloys. U. S. Patent 1,377,713, May 10, 1921; Chem. Abs., vol. 15, 1921, p. 3069.

Copper-nickel alloy is melted and bessemerized in a basic converter until all or most of the Ni is volatilized, and the fumes are collected as nickel oxide.

338. Sefton-Jones, H. Extracting and Refining Nickel. British Patent 187,111, Sept. 16, 1921; Chem. Abs., vol. 17, 1923, p. 967.

Ingots or other masses of pure Ni are made from impure nickel oxides by partly reducing the product with dilute HCl or a mixture of HCl and HF, drying and consolidating the product under pressure, and finally subjecting the masses to calcination, using reducing and desulfurizing agents, such as charcoal and lime. In modifications the preliminary reduction may be complete, or the impure oxide may be agglomerated before reduction and the reduced product crushed before the subsequent lixiviation.

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REFINING OF METAL, ELECTROMETALLURGICAL

339. Bogitch, B. Sur un procédé de électrodyse du nickel. [Electrolysis of Nickel.] Compt. rend., vol. 188, No. 4, Jan. 21, 1929, pp. 328–329; Eng. Index, 1929, p. 1280.

Nickel rods 20 mm. in diameter and more than 99.92 percent pure Ni have been prepared from nickel alloys containing 10 percent of impurities by deposition from a solution of nickel chloride above 65° C., using cathodes of thin nickel wire 0.5 mm. in diameter. The impure electrolyte from the anode compartment is purified for further use with nickel hydroxide.

340. Fink, C. G., and Rohrman, F. A. The Preparation of Pure Electrolytic Nickel. Am. Electrochem. Soc., Preprints 57–2 and 58–8, 1930, pp. 11–24, 83–100; Eng. Index, 1930, p. 1200.

Classifies methods for removing copper and nickel-copper electrolytes, and discusses a method for rapid removal of more than 90 percent of copper present as an impurity in nickel solutions. Further discussion describes effect of pH, current density, metal-ion concentration, temperature, and agitation upon cathodic deposits.

341. Guess, G. A. Electrodeposition of Nickel From a Nickel-Copper Anode. British Patent 118,629, Aug. 14, 1918; Chem. Abs., vol. 13, 1919, p. 95.

A nickel-copper anode in a $NiSO_4$ solution is maintained in contact with a reagent that with $CuSO_4$ forms an insoluble Cu compound and a noninjurious sulfate. The cathode is screened from the reagent and receives a deposit of Ni. Suitable reagents are limestone, CaO, or similar alkaline earths, which give insoluble sulfates, or $NiCO_3$, which forms additional $NiSO_4$. The reagent may be kept in suspension, in which case the cathode is in a porous pot. Alternately, pieces of the reagent may be placed in a porous pot around the anode. The electrolyte may be heated to 60°–80° C.

342. ———. A Process for Electrolytically Refining Nickel. Trans. Am. Electrochem. Soc., vol. 35, preprint, 1919; Chem. Abs., vol. 13, 1919, p. 816.

Electrolytic refining of nickel containing Cu and Fe produces a Ni deposit containing only 0.001 percent Cu. Iron goes into solution and accumulates, whereas Cu dissolves and is precipitated continuously, owing to a suspension of $CaCO_3$ in the electrolyte. The salt formed from the Cu in solution, $2CuO{\cdot}2NiO{\cdot}SO_3$, settles with $CaSO_4$ as a mud. The cathode is enclosed in a canvas bag to insure freedom from mechanical impurities. It is necessary to treat the converter matte with dilute H_2SO_4 or, by fusion, with coke and Na_2SO_4. Three sheet-lead or sheet-aluminum cathodes 15 by 15 cm. are suspended in canvas bags in each tank. The electrolyte consists of $NiSO_4$ solution containing 5.5–6.5 percent Ni; it is maintained at 40°–50° C. The accumulated mud is removed and reduced by fusion to an Ni–Cu matte which is dead roasted, reduced, cast into anodes, and used in Cu refining baths for recovery of Ni as sulfate.

343. Holloway, G. T. Process for Refining Nickel Copper Matte. Canadian Patent 177,920, June 16, 1917; Chem. Abs., vol. 11, 1917, p. 2891.

The sulfur content of the matte is reduced sufficiently for electrolytic refining by adding blister Cu, crude Cu, or Cu matte to produce an alloy.

344. Pring, John N. (assigned to Elmer A. Sperry, Brooklyn, N. Y.). Refining Nickel. U. S. Patent 874,864, Dec. 24, 1907; Chem. Abs., vol. 2, 1908, p. 1203.

Impure or crude nickel is refined by treating it in suitable solution with a soluble sulfide, treating the liquid which bears the resulting solids with a solvent for the foreign bodies, separating the remaining solids and electrolyzing them in an electrolytic cell in contact with an inert anode, and depositing nickel at the cathode.

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